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CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions, and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (*b*) abstracts or reviews of important meteorological papers and books, and (*c*) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, **but the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW or SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

BACK NUMBERS OF THE REVIEW WANTED.

As the surplus of MONTHLY WEATHER REVIEW, February, April, June, July, and August, 1919, is exhausted, recipients who do not care to retain their copies will confer a favor by using attached addressed, franked slip. The return of other issues of 1919 and earlier years will also be appreciated.

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 48, No. 2.
W. B. No. 706.

FEBRUARY, 1920.

CLOSED APR. 5, 1920
ISSUED May 3, 1920

PAPERS ON SLEET AND GLAZE ("ICE STORMS").

The freezing of rain onto wires, trees, and streets is so disastrous to telephone, telegraph, and power lines and radio-station aerials, to trees, and to transportation facilities that such means as can be employed to combat the formation of ice should be made ready before an "ice storm" begins. This involves forecasting the conditions which will cause the glaze to form, i. e., conditions such that liquid drops of water will fall from a relatively warm wind into cold air near the ground. The occurrence of sleet as well as the formation of glaze usually marks such a condition of the atmosphere and thus is a valuable (and noisy) index to glaze formation.

While the form of the precipitation reaching the earth's surface allows a fairly accurate surmise to be made as to critical temperatures aloft, actual observations by means of kites or airplanes, taken in conjunction with observations made at the surface, offer the best basis for "ice-storm" forecasts.

The first article indicates the general conditions under which sleet (and glaze) is formed, and the second discusses the actual meteorological features accompanying the storm of January 20 to 25, 1920, long to be remembered for the great destruction and inconvenience caused by the thick ice which formed over hundreds of thousands of square miles in the eastern United States.—EDITOR.

THE NATURE OF SLEET AND HOW IT IS FORMED.

By CHARLES F. BROOKS, Meteorologist.

[Weather Bureau, Washington, D. C., Apr. 5, 1920.]

SYNOPSIS.

Whereas in current practice in the United States, *sleet* is that form of precipitation which is not snow, rain, or hail, an attempt to make a detailed descriptive and genetic definition seems advisable, and 30 cases of sleet are analyzed as a basis:

Sleet, a rattling type of ice precipitation formed in the free air, has the following characteristics: *Size*, smallest dimensions of largest pieces less than 6 mm. (¼ inch); *form*, angular, irregular, or nearly spherical; *structure*, nongranular ice, part or all of which is cloudy or bubbly (except in extremely small drops), not more than one clear layer.

A sleet particle may be (1) a snowflake partly melted and refrozen, (2) a frozen raindrop, or (3) a frozen combination of snowflake, and raindrop or liquid (not undercooled) cloud droplets.

A generalized vertical section of sleet weather shows sleet as occurring usually with a cloud from which snow is falling through a stratum of air having a temperature above freezing and into air with a temperature below freezing.

INTRODUCTION.

Snow, sleet, rain, and hail are the names applied in the United States to all kinds of precipitation falling to earth out of the free air. Rain and snow need no definition here, and hail, with its large size, usual concentric layer structure, and association with strong thunderstorms, is definitely pictured in the minds of most observers. Thus, sleet, more or less by elimination, covers the great variety of ice particles which seem to give us frozen pictures of every step in the melting transition from snowflake to raindrop. In what category should "graupel" those granular white pellets, like compact miniature snowballs be placed—snow, sleet, or hail? Various names have been applied abroad, e. g., *snow pellets*, *soft hail*, *winter hail*, *grésil*, *Graupeln* (1).

SLEET DEFINITIONS.

It is no wonder then that there has been some difficulty in defining *sleet*. This will be obvious from a glance at Dr. Cleveland Abbe, jr.'s article, "American Definition of 'Sleet.'" (2) So far as the application of the word *sleet* to a form of precipitation generated in the atmosphere is concerned, there are the following outstanding features evident in this discussion: That "*nothing is sleet that does not rattle on a tin roof or against a window pane*," (C. Alphonso Smith), and that *all sleet is either frozen rain drops or a mixture of rain and snow*. But how can a mixture of rain and snow rattle? Only by being a refrozen or partly refrozen mixture of the two. In the British Isles *sleet* is defined as, "Precipitation of rain or snow together or of partially melted snow." (7) The Weather Bureau's sleet committee, in consequence of not being able to make compatible the definitions mentioning a mixture of rain and snow on the one hand, and frozen raindrops on the other hand, omitted the former conception entirely and the then current (since about 1897) Weather Bureau instructions were continued:

> Care should be taken in determining the character of precipitation when in the form of sleet or hail. Only the precipitation that occurs in the form of frozen or partly frozen rain should be called *sleet*. Hail is formed by accretions consisting of concentric layers of ice, or of alternate layers of ice and snow. It frequently happens that snow falls in the form of small round pellets, which are opaque, having the same appearance as snow when packed. This should never be recorded as sleet.—*Weather Bureau* "Instructions for preparing meteorological forms," Washington, 1913, paragraph 119.

The Weather Bureau thus defined *sleet* as a frozen, hard, practically spherical form of precipitation, and differentiated between *sleet* and *snow* on the basis of whether or not the form of precipitation looks like a frozen or partly frozen raindrop. The distinction is a hard one to draw in practice, for there is no break in the gradation between snow and rain, or therefore, in the gradation of the frozen counterparts of this transition. There was no place in the Weather Bureau definition for irregular pieces of ice. These considerations led to the omission of all but the first sentence in the paragraph 119 quoted, as published in the revised instructions, which went into effect January 1, 1920. Uniformity in practice in re-

cording sleet, however, demands a definition. This can be purely descriptive, or, better still, in part genetic so that the two elements of the definition will reinforce each other and leave no doubt as to what is meant.

Etymologically, *sleet* rattles on striking a hard object, and, therefore, it includes those irregular, partly melted, refrozen snowflake remnants, as well as the small, nearly spherical "frozen raindrops." It is much easier to differentiate a form of precipitation that rattles from one that does not than to draw the line between one that looks like a frozen raindrop and one that does not. A man who has to face a sleet storm places in the same category all forms that sting.

OBSERVATIONS OF SLEET PARTICLES.

The discussion of sleet definition and mode of formation aroused at the Second Pan American Scientific Congress, December 30, 1915, by Dr. Frankenfield's paper, "Sleet and ice storms in the United States," (3) made it obvious that statistical evidence as to the actual nature of sleet particles was necessary. So, 22 of the subsequent occurrences of sleet which I observed at New Haven, Conn., in 1916, 1917, and 1918 were carefully noted.

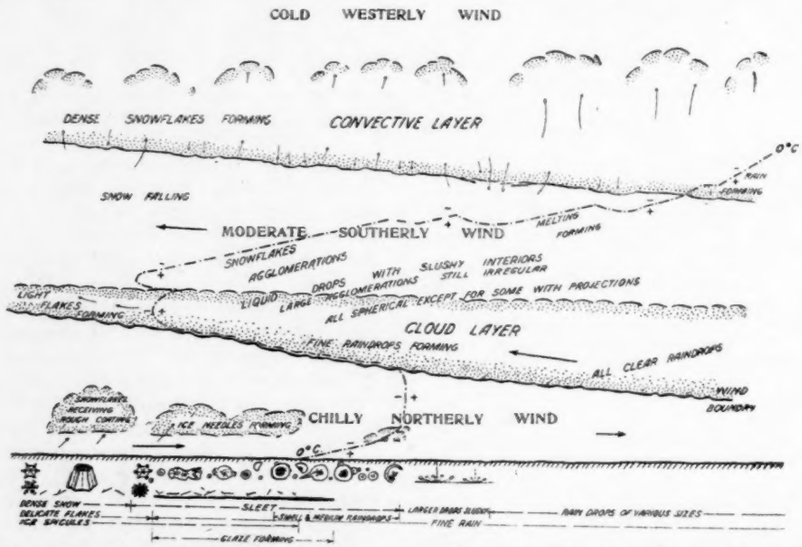

FIG. 1.—Composite diagram showing north-south section of the lowest 3 or 4 kilometers of the atmosphere probably responsible, at least on some occasions, for the formation of the various types of snow, sleet, and rain and the formation of glaze as shown at bottom. (If freezing temperatures near the surface extended beyond the right of the diagram some of the sleet would never have started as snow).

Observations of 8 other cases in 1912, 1914, 1919, and 1920 bring the total up to 30. The dates were as follows:

1912: February 26 (Cambridge, Mass.).
1914: January 31 (Cambridge, Mass.).
1916: January 12, 20, 30; February 2, 12, 13, 18; March 6, 8, 14, 15; April 8 (New Haven, Conn.).
1917: January 31; February 5, 19; March 17; April 5, 26 (New Haven, Conn.).
1918: February 6, 9; April 10, 11 (New Haven, Conn.).
1919: March 15; December 14 (Washington, D. C.).
1920: January 22; February 4, 5, 14 (Washington, D. C.).

The details of some of the occurrences are, perhaps, worth publishing. The following are arranged roughly to show the transition in form between the but slightly melted refrozen snowflakes to what may have been actual frozen raindrops:

February 2, 1916.—The sound of falling, hard ice particles began before dawn. At 7:15 the ground was white with a covering half snow and half sleet. The snow was in single crystals generally of compact form, about 0.5 mm. thick and 2 mm. in diameter. Most of the falling sleet particles were ¾ to 1 mm. in diameter, and some of the irregular pieces were 2 mm. long. Except for distortions the form of most approached the spherical. All particles were slightly cloudy inside except some of the smallest, which looked like clear ice. This sleet was evidently formed by the melting and refreezing of separate snowflakes, and particles were small because the snow crystals, being dense, did not become massed into large flakes while passing through the warm current.

Precipitation ceased from about 7:40 to 8:10 a. m. Then fine, liquid drops of rain, and some sleet fell for 15 minutes. Some glaze formed, as the temperature of the lower air was about −2° C. From 8:30 to 9:05 a. m. larger sleet fell. It was of irregular, half-melted, refrozen flakes, which looked white while falling through the air. Accompanying this sleet fall there were two types of snowflakes—one kind thin and light (a perfectly symmetrical 12-pointed one was seen) and the other kind thick, almost like a pellet. More glaze formed at about 9:15 and some sleet like that of the early morning fell again. Snow without accompanying sleet continued for the rest of the day from shortly after 10 a. m. with a northeasterly wind and falling temperature. The compact snowflakes seem to have come from a layer of cloud above a relatively warm, probably southerly, wind which must have been flowing over the cold surface wind. The intermissions in the precipitation may have been due to breaks in this upper cloud, and the final cessation of sleet due to the fall of temperature of the southerly wind to below 0° C. The fine raindrops, thin snowflakes, and the large, white sleet seem to have fallen from a low cloud the vertical extent of which reached from the lower cold current and through the warm one to a height exceeding the level where a temperature below 0° C. again occurred. From the base of such a cloud the thin snowflakes could fall without melting, in the middle the liquid raindrops could be formed, and light snowflakes forming in the top and aggregating on falling through the warm layer would refreeze on passing through the cold air near the surface.

The warm wind aloft seems to have strengthened during the afternoon, and its under boundary must have been low, for from 4 to 9:10 p. m. barometric ripples of about 0.05 inch amplitude in intervals of a few minutes were traced by the barograph, and the pressure was falling. Some sleet occurred at 8:40 p. m. and the snowflakes later were hard and thick. The evening temperature was about −5° C.

February 18, 1916.—Melting sleet fell with a brisk rain between 4:10 and 4:25 p. m. The surface wind was about south, and the temperature 1° C. At 4:30 p. m. the sun shone and the wind changed to westerly. The sleet was obviously the partly refrozen remnants of half-melted snowflake agglomerations. They ranged from irregular white pieces about 2 mm. in diameter to hard, clear-surfaced ones about 1 to 2 mm. in diameter. The white ones became transparent very quickly on melting. Sleet is commonly formed from melting snow falling as in this case through a wedge of cold air which arrives at a moderate elevation just before the surface wind shifts on the passage of a low-pressure trough.

January 30, 1916.—A light fall of sleet occurred from 7:30 to 7:40 a. m. The pellets were generally oblate spheroids of 1.5 to 4 mm. diameter, the majority being 3.5 to 4 mm. Adhering, minute drops of

ice (one of less than 0.5 mm. diameter was seen) and protruding thin plates and arms of unmelted snowflakes brought the length of some up to 7 mm. Most had snowy interiors, but were largely of clear ice. Many (from the impact of their fall, perhaps) became hollow, as if the drop had frozen only to a depth of 1 to 1.5 mm., and then the water had run out. A misting rain began coincidently with the sleet-fall, and glaze formed till about 11 a. m., when the temperature rose to above freezing. The morning temperature was −1° C., and the wind light east. The large size of the sleet seems to have been due to the partial melting and refreezing of considerable agglomerations of flakes, a conclusion which is borne out by the occurrence of remnants of more than one flake in a single sleet particle. The minute drops were probably from the melting of individual crystals or from intercepted drops formed otherwise.

March 14, 1916.—A little rain began falling at 4:20 p. m. and sleet at about 7:30 p. m. Each particle was a thick and hard snowflake which had evidently been partially melted and refrozen in the lower air. The six points of the flakes were in many cases reduced to ice beads, while the inside parts still showed the delicate structure of a snowflake.

March 15, 1916.—During the night the northeast wind increased to strong and the temperature fell to −5° C. at 7 a. m. and to −7° C. at noon. All morning fine drops of liquid rain and small grains of snow 0.2 to 0.3 mm. in diameter were falling. At 1:10 p. m. the sky became very dark and at 1:20 large sleet began to fall (the small grains continuing), in a heavy shower at first. This sleet was 1.5 to 5 mm. in diameter, almost spherical, whitish and bumpy on the surface (probably from falling through a cloud of undercooled droplets), but with an outer layer of clear ice immediately below the surface and an inner core of cloudy ice. There were all sizes from 5 mm. down perhaps to 0.1 mm. between 1:30 and 2 p. m. Then snowflakes were first seen, and by 2:10 all the precipitation was in the form of snow. Many of the snow crystals were hard and fat, and there were several large, softer flakes.

February 4, 1920.[1]—After some heavy rain on the preceding evening, light rain and light sleet began at about 8 a. m., the sleet being nearly spherical (there were some hemispheres), 0.2 to 2 mm. in diameter, and all particles having cloudy centers. The light rain continued throughout the day, the sleet became heavy by late morning, and during two hours in midafternoon was mixed with snow needles (probably from the low clouds). The wind was brisk NE. and the low nimbus clouds, when visible, moved in turbulent manner from the ENE. At 5:45 p. m., among the large quantities of sleet falling, one pellet with an arm of a snow crystal projecting about 2 mm. beyond the surface, making the particle about 4 mm. long, was observed. The depth of sleet fall to 6:15 p. m. was 5 cm. The heavy sleet and light rain continued till about 8:30 p. m., after which the light rain and possibly some fine needles of snow fell during the night.

February 5, 1920.—In the morning low scud was moving from the northeast and small raindrops, scattered snow needles, and very small sleet, for the most part about 0.2 to 0.6 mm. in diameter, fell in small quantity. The wind was north-northeast to north. Snow needles were again seen at 2 p. m. Larger sleet, of ordinary character, fell in the late afternoon and in a shower during the evening. Light rain continued throughout. The clouds during the late afternoon were much less dense than on the preceding afternoon, for the daylight lingered noticeably longer.

January 31, 1914.—For a few minutes during the formation of glaze some sleet fell. "The individual pieces were generally spherical, but many were angular; some were flat on one side [split pellets], and others were agglomerations. The frozen drops varied between 0.5 mm. and 4 mm. in diameter. One pellet 3 mm. in diameter had two pellets 1½ and 1¼ mm. in diameter stuck to it, and one of ¾ mm. stuck to the 1½ mm. one. (See fig. 1). The structure of the sleet showed plainly [that] * * * snowflakes had passed into an air stratum whose temperature was above 0° C.; and [that] some, on reaching the colder layer below before entirely melting, froze. This is shown by the presence of snowflake skeletons, by angularity, and by the almost universal prevalence of minute bubbles in the ice. The unfrozen rain which reached the ground was rain formed within the warmer stratum and of entirely melted snowflakes. The short duration of the sleet may be explained by assuming that before and after its occurrence the warmer layer was so thick that none of the snow passed out of it partially melted." (4)

SUMMARY OF THE 30 OBSERVATIONS OF THE CHARACTER OF SLEET.

Size.—Most frequent, 2 to 3 mm. diameter. Extremes measured, 0.2 to 5 mm. diameter; irregular pieces, maximum length more than 10 mm.

Form.—Spherical, or nearly so, and not accompanied by irregular or angular pieces, 6 cases. Irregular or angular pieces, 20 cases. (Details not recorded in 4 cases.)

Structure.—Cloudy or bubbly cores—noted in all sleet, except for some of the very smallest drops. Ice shell, wet interior, 2 cases. Snow crystals or remnants visible, 10 cases.

Attendant rain or snow.—Liquid rain coincident with sleet fall, 22 out of 26 cases in which precipitation was noted. Sleetfalls immediately preceded, accompanied, or followed by snowfall, 15 noted.

A NEW DESCRIPTIVE DEFINITION OF SLEET.

These sleet observations are, perhaps, sufficient to validate the following descriptive definition:

Sleet, a rattling type of ice precipitation formed in the free air, has the following characteristics: *Size*, smallest dimensions of the largest pieces less than 6 mm. (¼ inch); *form*, angular, irregular, or nearly spherical; *structure*, non-granular ice, part or all of which is cloudy or bubbly (except in extremely small drops), not more than one clear layer.

This definition differentiates sleet from rain, since sleet is of ice particles; it differentiates sleet from snow, since sleet rattles and, unlike graupel which also rattles, bears evidence of having been in at least a partly liquid state, and it differentiates sleet from hail, since hailfalls in which the largest pieces are less than 6 mm. (¼ inch) through, are rare.

HOW SLEET IS FORMED.

What can observations of the nature of sleet tell as to its genesis?

Snowflake origin.—In practically all sleetfalls there is unmistakable evidence of snowflake origin; particles show snow crystal remnants, angularity, or included bubbles. Furthermore, the association of sleetfalls with coincident, immediately preceding, or immediately following snowfalls points in the same direction. In only 4 of the 30 sleet occurrences cited are indications of snow association lacking; and in these 4 the sleet pellets had cloudy cores, which may have been the last, unmelted remnants of snowflakes. Thus, we may say with confidence that few sleetfalls occur in which at least some of the sleet particles are not partly melted, refrozen snowflakes.

Frozen raindrops.—How common are frozen raindrops, i. e., sleet pellets formed from entirely liquid raindrops? A cake of artificial ice, frozen from the outside, has a cloudy core, so a frozen raindrop might reasonably be expected to have a cloudy core. There is nothing to indicate that frozen raindrops do not occur in some sleetfalls, either from the freezing of the raindrops from snowflakes entirely melted in passing through a warm stratum aloft, or from raindrops actually precipitated from the warm wind. The formation of raindrops from any but small snowflakes seems unlikely under sleet-forming conditions, as there is room aloft for but a relatively small thickness of air at temperatures above 0° C. Frozen raindrops will form from any drops cold enough,[2] which are of sufficient size to be rippled in falling through the air, and from any undercooled drops that collide. Several

[1] See also pp. 78 and 110 of this REVIEW.

[2] The following note may be illuminating on this point:
Super-cooled water.—With reference to this subject, which was mentioned in the last Circular (No. 23), Dr. John Aitken writes: "I was much surprised to read in your 'Official Notices,' No. 23, that the existence of pure water as a liquid at temperatures below the freezing point 'is naturally regarded as exceptional.' Now, this is far from the case. It is the rule water can no more begin to change to ice at its 'freezing point' than it can change to vapor at its 'boiling point,' or from vapor to water at its 'condensing point,' unless there is a 'free surface' present at which the change can take place. Water has always to be cooled some degrees below its 'freezing point' before ice begins to form. Nothing in nature with which water is in contact, such as particles of soil, stones, grass, etc., act as 'free surface,' though some of them seem to start the action with less subcooling than others. Yet all [?] require 1° or 2° C. subcooling before they start the change. The only substance known that will cause freezing to begin just below the 'freezing point' is a piece of ice or a snowflake. This slowness in starting the freezing and the time taken to freeze all the water on the bulb makes 'wet' and 'dry' readings of little value for temperatures about the 'freezing point.'"—*Meteorological Office Circular* (London), No. 24, May 24, 1918, p. 2.

observed facts indicate that small, undercooled raindrops occur not infrequently: (1) Droplets that freeze onto objects without entirely flattening out; (2) the dryness of icy posts on which raindrops are continually falling; (3) the formation of glaze from raindrops on twigs and roofs where snowflakes had just been melting (**5**). Theoretical considerations of the rate of cooling of a raindrop and the known temperatures and thickness of below-freezing layers of air through which liquid raindrops fall confirm this (**4**) (**6**). The maximum size which such drops can attain without rippling on falling, is at least 0.5 mm. (measured on several occasions) and is probably 1 mm., and perhaps more in relatively calm air (in which the "air-speed" of the drop does not change as in passing through turbulent air).

The descriptive definition of sleet given on page 71 may be strengthened by the addition of the following sentence:

A sleet particle may be (1) a snowflake partly melted and refrozen, or (2) a frozen raindrop, or (3) a frozen combination of snowflake and raindrop or liquid (not undercooled) cloud droplets.

GRAUPEL.

Coated snowflakes.—A snowflake on falling through a cloud of undercooled liquid droplets is likely to become coated with a layer of rough ice if there is sufficient turbulence to make it fall with different sides downward. Such a coated snowflake becomes a pellet of the type usually known abroad as *soft hail, Graupeln,* etc. If, however, the falling crystal presents the same face downward throughout its passage through the wet cloud, the intercepted cloud particles may arrange themselves in accordance with the axes of the snow crystal. The following notes were written about such a case observed at New Haven, Conn., March 10, 1918, for a half hour at about noon; surface wind, west-north:

In the center of an intense cyclone, while the pressure oscillated slightly under the influence of the changing proportions of cool and warm air layers above, a fall of "soft hail" in the form of truncated fluted hexagonal pyramids, 3 to 5 mm. high and 3 to 5 mm. in diameter across the base, occurred. The tops of the pyramids were formed by symmetrical snow crystals and so were the bases. The sides were grooved corresponding to the indentations of the edges of the snow crystals. The texture was relatively coarse, and the structure partook of the character of mountain hoar frost [rime] which has formed in a windy fog, from the congealing of the cloud particles onto the already formed ice crystals.

Evidently there had been a fall of snowflakes from the upper nimbus, and these in passing through a quiet layer of stratus or fracto-nimbus had kept their horizontal positions and in this way accumulated more and more cloud droplets as they settled and grew in diameter. Mixed with the fall of "soft hail" were ice needles, representing, apparently, the direct condensation into ice which was taking place within the scud.

Genetically there is really but little difference between this collection of cloud particles on a falling snowflake and the collection of undercooled [?] raindrops on the falling hailstone. If the fracto-nimbus were turbulent the deposits might occur on all sides, making a rounded pellet.

Clouds at 8 a. m.: Layer at about 700 m. from west, Fr.Nb. below from northeast. Northwest wind-shift [followed with] snow squall [lasting till] 3 p. m.

A previously formed sleet particle may receive a rough coating by falling through a cloud of undercooled droplets.

SLEET, GRAUPEL AND HAIL CONTRASTED.

Sleet.—Partly melted snow or rain frozen while falling from a warm layer through a cold one. (Different from hail—not carried aloft by strong convection.)

Graupel.—Snowflake coated with rime on falling through a cloud of undercooled liquid droplets. (Different from sleet—temperature not above freezing aloft.)

Hail.—Accretion of snow and rain, usually in layers, formed by being carried by strong convection from a warm *up* to a cold level. (Different from sleet—no cold, surface layer necessary.)

VERTICAL SECTION OF SLEET WEATHER.

Figure 1 is a diagrammatic representation of the conditions which seem to be responsible for the formation of the various types of sleet observed. It is an improvement over its predecessor published in 1914 (**4**) in that it is more detailed and based on more observationst Still it is hypothetical in part, and it may be corrected by simultaneous observations at different levels on high towers and mountains or by means of kites, balloons, or airplanes.

CONCLUSION.

Close observation of the form of precipitation, of surface wind, temperature and pressure conditions, and of clouds, when interpreted in the light of some understanding of the processes of the atmosphere enable meteorologists to surmise with reasonable assurance what the winds and temperatures are aloft. Let us have *sleet* in our records always be significant of the probable occurrence of winds with above-freezing temperatures over a cold, surface layer of air.

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(**1**) **Hellmann, G.**
System der Hydrometeore, 1915. Translation in MONTHLY WEATHER REVIEW, July, 1916, **44**:385–392; January, 1917, **45**:13–16. Discussion by **C. F. Marvin,** pp. 17–18. For snow pellets, etc., see especially pp. 14–15; for sleet, p. 15; for glaze, pp. 16 and 18.

(**2**) **Abbe, Cleveland, jr.**
American definition of "sleet." Ibid. May, 1915, **44**:281–286.

(**3**) **H. C. Frankenfield.**
Sleet and ice storms in the United States, Second Pan American Scientific Congress, Proceedings, Washington, 1917. Vol. 2, pp. 249–257.

(**4**) **Brooks, Charles F.**
The ice storms of New England. Ann. Astr. Obs. Harvard Coll., vol. 73, pt. 1, pp. 77–84, 7 figs. Cambridge, Mass., 1914. (Quotation from pp. 78–79.) (Reviewed in MONTHLY WEATHER REVIEW, July, 1914, **42**:455–457.)

(**5**) **Budig, W.**
Glatteisbildung am 5 März, 1915. Met. Zeit., September, 1915, vol. 32, p. 426, fig.

(**6**) **Okada, T.**
Notes on the formation of glazed frost. Jour. Met'l Soc. of Japan, No. 5, 1914, 10 pp. (Reviewed in *Nature* (London), Oct. 8, 1914, p. 149.)

(**7**) **British Meteorological Office.**
Meteorological glossary. 4th issue. London, 1918, p. 341.

A WEATHER CONDITION WHICH PRODUCES GLAZE IN NORTHERN NEW YORK.

By DOUGLAS F. MANNING.
[Alexandria Bay, N. Y., Mar. 4, 1920.]

An interesting state of weather occurs here not infrequently during January, February, and March. Such a condition prevailed during March 2 and 3, 1920, proving that the intensely cold northerly winds sometimes extend only a short distance above the earth's surface.

Under such conditions, there is a fresh to brisk northerly to northeasterly wind of a temperature between 10° below zero F. and zero, or a few degrees above, and a sky covered with a warm-looking, smoky-appearing strato-cumulus cloud at moderate altitude moving slowly from the southwest or west and with which the sun, when seen shining through the occasional clear space, is a ball of lurid red.

Sometimes large feathery flakes of snow fall, the fact of the large flakes proving a warmer current aloft, and at

times when the condition is well-developed a fine rain falls covering everything with a coat of glaze ice.

At such times an examination of the weather map shows we are to the north of the axis of a trough of low pressure and that but a little way south of us warm west to southwest winds are blowing and no doubt overriding this cold northerly air, producing the clouds and sometimes rain. As a rule this condition is followed by a shift of wind to SW. and a rapid rise in temperature, the clouds all disappearing.

BOUNDARY BETWEEN A SOUTH WIND AND AN UNDERRUNNING NORTHEAST WIND.[1]

By CHARLES F. BROOKS.

[Blue Hill Observatory, Mass., May, 1913.]

In the late afternoon and evening of May 3, 1913, an anticyclone began to approach Blue Hill from the north. During the day a sea-breeze of three hours' duration had prevented the maximum temperature (80°F.) from occurring until the middle of the afternoon at the summit of the hill (195 m.). The wind remained in a southerly direction till 9 p. m. with momentary exceptions, marked by sharp drops in the thermograph curve.

The wind at the base station (64 m.) became northeast at 5:20 p. m. and therefore for several hours a considerable temperature inversion existed between the base and summit, at one time amounting to 14°F. At 7 p. m. the dividing line between the northeast wind and the south-southeast wind was across the summit of the hill in an east-west direction. This line was very sharp, so-sharp that I could stand with the breeze from the northeast blowing on one cheek and that from the south on the other. At this time, as shown by the oscillations of the hygrograph curve up and back again whenever a small volume of northeast wind blew through the instrument shelter, the relative humidity on the dividing line was 80 per cent on one side (northeast) and 40 per cent on the other (south).

With the normal evening cooling the humidity presently reached 100 per cent on the dividing zone, thereby producing a fog. The pressure began its rapid rise at this time. Before long the stratus cloud rose from the top of the hill (3 a. m., by hygrograph), and by 7 a. m., May 4, was some distance above, its appearance giving an inverse "mammato" effect. At about noon the sun first broke through the cloud sheet, and by sundown most was gone.

(NOTE.—Another occasion on which I observed a similar sharp dividing line between winds from two directions was on July 25, 1912 near the Schilthorn, Switzerland. In the late afternoon, when there were thunderstorms in the vicinity, a cloudy current coming up the south side of a ridge on the east met a clear current up the north side with the result that a vertical cloud wall perhaps 100 meters high was formed.)

[1] *See* C. F. Brooks, Three ice storms, *Science*, Aug. 8, 1913, pp. 193-194, for descriptions of somewhat similar conditions.

THE PRECIPITATION OF SLEET AND THE FORMATION OF GLAZE IN THE EASTERN UNITED STATES, JANUARY 20 TO 25, 1920, WITH REMARKS ON FORECASTING.

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., Mar. 29, 1920.]

SYNOPSIS.

An attempt is made, by means of accurate charts of precipitation during the previous 12 hours, current temperature, pressure, and lines of wind flow, in combination with such aerological data as could be obtained, to construct cross-sections of the lower 3 kilometers of the atmosphere, during the period January 20 to 25, 1920. From such charts are shown the actual processes which produce rain, sleet, and snow, separately and in combination, in such a manner as to produce the ice cover, which is called an "ice storm." The condition is, briefly, a cold northerly wind underrunning a warm southerly current, forcing the latter aloft. The vertical distribution of temperature, shown in the cross-sections, indicates the manner in which the isotherms in that territory covered by the northerly wind rise normally until the level of the overrunning southerly wind is attained, where the isotherm swerves sharply northward. The distance that the isotherm of freezing reaches is indicated by the northern limit of the precipitation of sleet.

An empirical relation was obtained between the distance from the wind-shift line to the 32° isotherm and (1) the width of the glaze belt, (2) the width of the sleet belt, (3) the distance of the center of the sleet belt north of the 32° isotherm, (4) the width of the glaze belt on a meridian 4° east 12 hours later, and (5) the width of the glaze belt on a meridian 8° east 24 hours later. These values are presented with the full realization that they may be true for this particular storm only, and are as follows:

(1) The width of the glaze belt=the distance between the 32° isotherm and the wind-shift line;

(2) The width of the sleet belt=0.7 × the distance between the 32° isotherm and the wind-shift line;

(3) The distance between the 32° isotherm and the center of the sleet belt=0.8 × the distance between the 32° isotherm and the wind-shift line;

(4) The width of the glaze belt 4° east, 12 hours later=0.9 × the distance between the 32° isotherm and the wind-shift line; and,

(5) The width of the glaze belt 8° east, 24 hours later=0.8 × the distance between the 32° isotherm and the wind-shift line.

The importance of the wind-shift line in forecasting the region over which sleet or glaze are likely to occur is strongly emphasized, since it marks the point of ascent of the southerly wind and hence is the basis upon which rests the location of this type of precipitation.

INTRODUCTION.

Of all types of storms, there are few which have the wide-spread economic effects of the so-called "ice storm." Not only is traffic, both on railroads and in cities, impeded and often completely tied up, and telephone and telegraph lines crippled, but accidents are numerous also. Moreover, when rain falls on a region previously covered with snow and produces an ice glaze, the snow is held immovable and the glaze forms a gliding surface over which subsequent snow will drift with little hindrance. In New York City recently, when the streets were more effectually blockaded by snow than at any time in the city's history, not a small part of the difficulty in its removal was attributable to the fact that there had been layers of ice formed at various levels in the snow, increasing the rigidity of the drifts and packing them more solidly.

Often such storms are local and do not have a wide-spread effect, but once or twice in a winter they occur over a large area of the country. They are caused, of course, simply by the precipitation of rain upon a region the temperature of which is at freezing or below. In many cases, it is not long before all surfaces exposed to the rain become heavily coated with a crystal-clear layer of ice, sometimes as much as an inch in thickness. This

type of storm has been called by the rather unsatisfactory name of *ice storm*. The ice cover which is formed is called by the English *glazed frost;* this is not satisfactory because it is not related to frost; the French *verglas* and the German *Glatteis* are more descriptive. Our word *glaze*, adopted by the Weather Bureau in 1916, comes nearest to a satisfactory designation for this condition.[1]

The conditions under which such precipitation is produced have been discussed in the preceding article by Dr. C. F. Brooks,[2] and the reader is referred to his article for an explanation of the processes taking place aloft which produce areas of snow, sleet, glaze, and rain, either singly or in combination. This paper proposes to discuss, as far as available data and legitimate speculation will permit, the conditions aloft as well as at the surface, and to show how they interact in a specific storm.

PLAN OF THE STUDY.

The winter of 1919–20 has been a particularly unpleasant one in the Eastern United States, owing, especially, to the great precipitation of snow in the northern portions, and of snow, sleet, and rain in the middle latitudes, which formed a solid, slow-melting cover. Perhaps the worst periods of this type were those of January 20–25 and February 3–6, the former covering practically all the territory east of the 100th meridian, while the latter was confined to the Atlantic coast States. The first period has been investigated the more thoroughly owing to its greater area and duration.

Forecasting.—The forecasting of sleet and glaze is very difficult because they occur so rarely that it is hard to sort out from the complex of the weather those conditions which so combine and operate as to produce this effect 12 to 24 hours later. The following conditions, according to Prof. H. C. Frankenfield, in "Weather Forecasting in the United States,"[3] are usually productive of sleet storms and glaze formation:

1. Low temperature and high pressure to the northward (between northwest and northeast.) * * *
2. Steep pressure and temperature gradients to the northward (between northwest and northeast.) * * *
3. Surface temperatures below freezing. * * *
4. Moderately high pressure and high temperature over the East Gulf and South Atlantic States. * * *
5. Northward looping of the isotherms. * * *
6. Gentle to fresh northerly winds, increasing by time sleet begins. * * *
7. Low pressure trough trending southwest to northeast between two HIGHS. The LOW is usually moving from the southwest, but sometimes from the northwest.

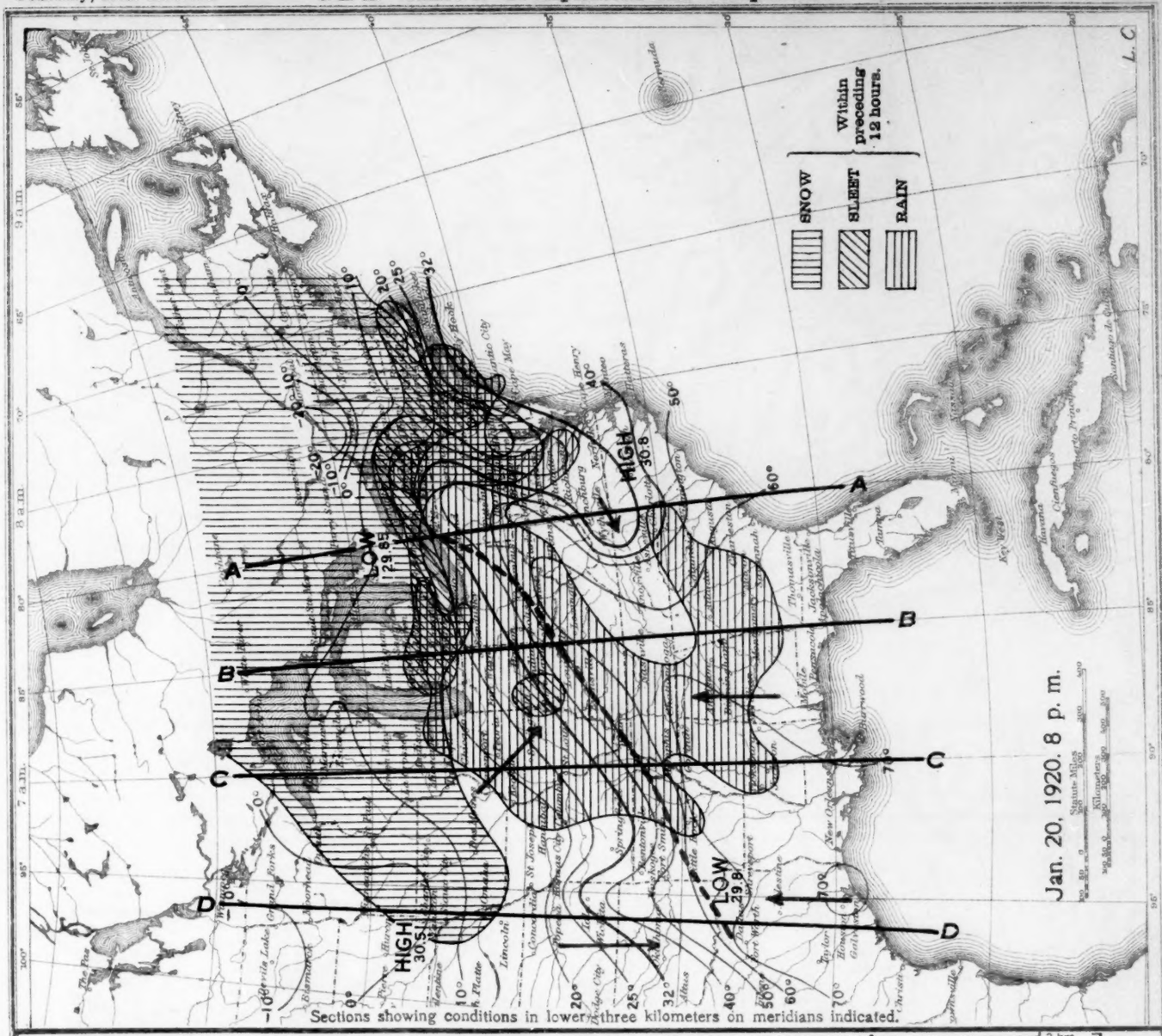
And, while it is possible, when such formations are present, to say that *sleet will occur* or that *glaze will occur*, it is rarely possible to forecast its location more definitely than to designate its center. But the width of the area is, obviously, a function of the temperature both at the surface and aloft, and of the strength of the north and south components of the underrunning and overriding winds. Even though the critical examination of a single storm is unlikely to shed as much light on these relationships as might be desired, nevertheless, such an investigation justifies itself in setting forth clearly throughout the period the conditions which did prevail together with the kind of precipitation and the regions over which it occurred.

Meridional sections of the atmosphere.—Besides the ordinary relations of barometric pressure and precipitation, it is necessary to investigate by means of meridional cross-sections the distribution of temperature, cloudiness, and wind velocity aloft; also to construct maps showing the areas over which precipitation in the form of rain, sleet, or snow, or combinations of these, occurred. In constructing the meridional cross-sections two assumptions are necessary—first, that the wind of southerly component continues aloft after leaving the ground, overriding the wind of northerly component; and, second, that the temperature of the wind of southerly component may be surmised from the following: (*a*) The temperature fall per degree of latitude as the southerly wind proceeds northward can give a clue as to the temperature of the wind after it has risen from the surface; (*b*) the dynamic cooling of the southerly air as it rises can be surmised from the amount of precipitation; (*c*) the northern limit of the isotherm of freezing is marked, with due consideration for the effect of wind velocity in keeping the sleet pellets and raindrops from falling vertically, by the northern limit of sleet or rainfall; and (*d*) the motion, type, and height of the base of the clouds tell much concerning the conditions aloft, where kite observations are wanting.

Width of sleet and glaze belts.—The width of the sleet belt and glaze belt are, of course, of prime importance in the forecast, and thus the forecast becomes primarily one of temperature; i. e., the predicting as accurately as possible the location of the horizontal freezing line. But while this can be a certain guide to the general location of sleet and glaze, there must be other conditions peculiar to the winds involved which will determine the width of the area over which precipitation will occur. At the outset the following considerations were suggested: (1) The steepness of the surface temperature gradient within the zone of northerly winds; (2) the strength of the southward component in the northerly winds; (3) the strength of the southerly wind aloft; (4) the difference between the surface temperature and the maximum temperature aloft; and (5) the determination of the height of the maximum temperature aloft. The last point is one that is subject to several considerations. If one considers the surface temperature in the southerly wind at some point south of the wind-shift line, or the line where the southerly component disappears and the northerly appears, it is possible to approximate the altitude of the freezing temperature by assuming an appropriate vertical temperature gradient, dependent upon the current conditions. Direct observation by kites is desirable, but where this is impossible, the current conditions can be surmised by allowing the vertical temperature gradient to depart from the normal shown by kites in accordance with the variation of other conditions from the normal, such as wind speed and snow cover. Again, after this southerly current leaves the ground its temperature must be dynamically lowered. Finally, the strength of the southerly component must be considered, for it is apparent that an increase of wind velocity with altitude, when the wind is bearing a temperature very high relative to that at the surface, is certain to carry the warm air farther north over the cold layer than would otherwise be the case. All of these three factors must be included in any speculation regarding the altitude of the freezing temperature at its northern extremity aloft.

Charts.—To aid in the discussion of the data from the various standpoints mentioned above, the accompanying series of charts has been devised. The even-numbered Charts II, IV, VI, etc., consist of two maps, the upper showing the sea-level pressure distribution, and the lower showing the instantaneous stream lines at the same time. The stream line map must not be misunder-

[1] Abbe, Cleveland, jr.: American definition of "sleet." MONTHLY WEATHER REVIEW 1916, 44: 281–286.
[2] Brooks, Charles F.: The nature of sleet and how it is formed. This REVIEW, pp. 69–72.
[3] U. S. Dept. of Agriculture, Weather Bureau: Weather forecasting in the United States, Washington, 1916, pp. 257–260.



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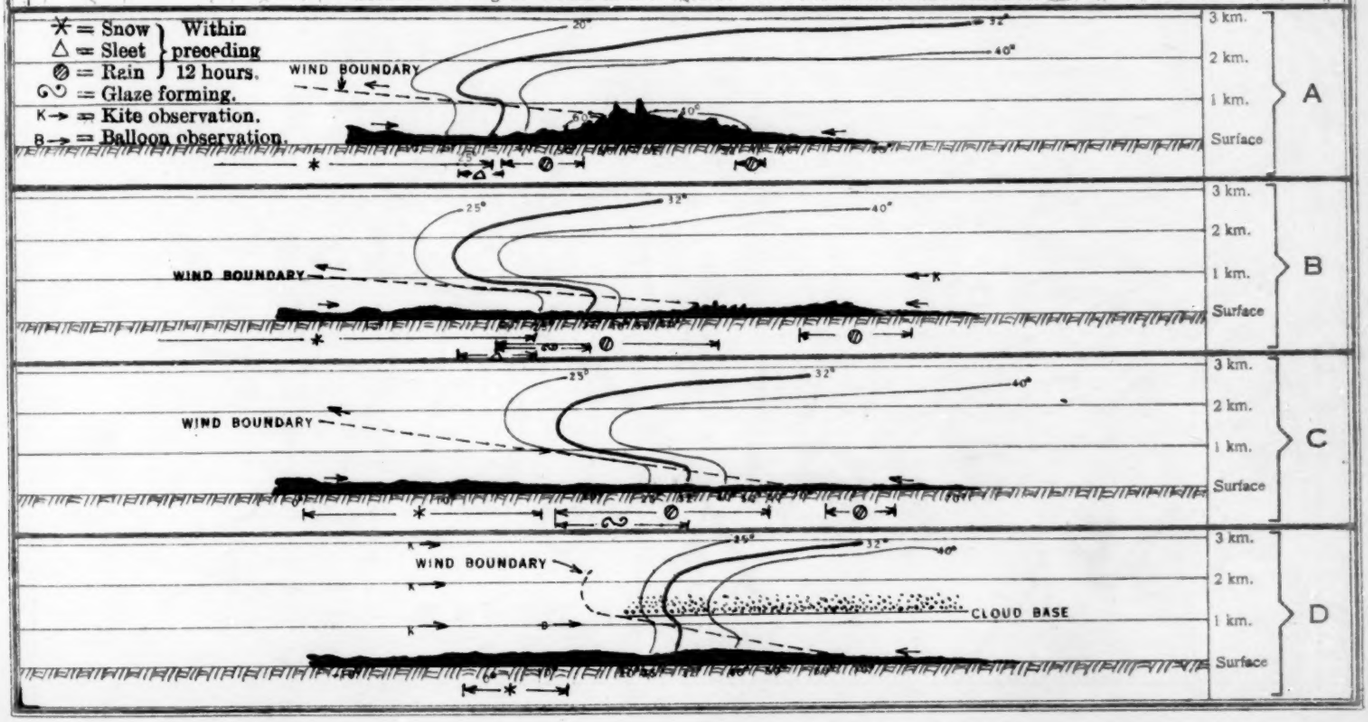

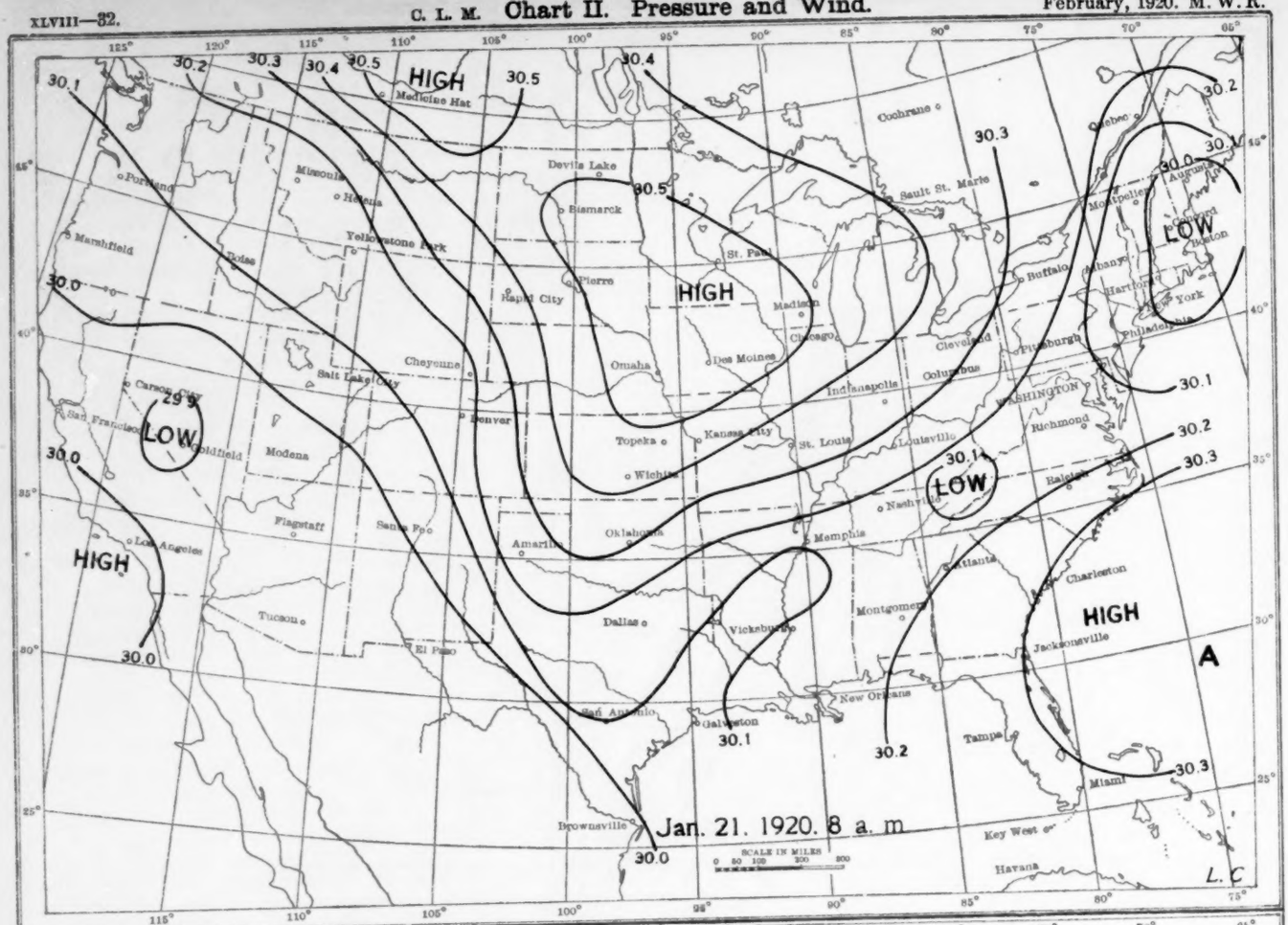
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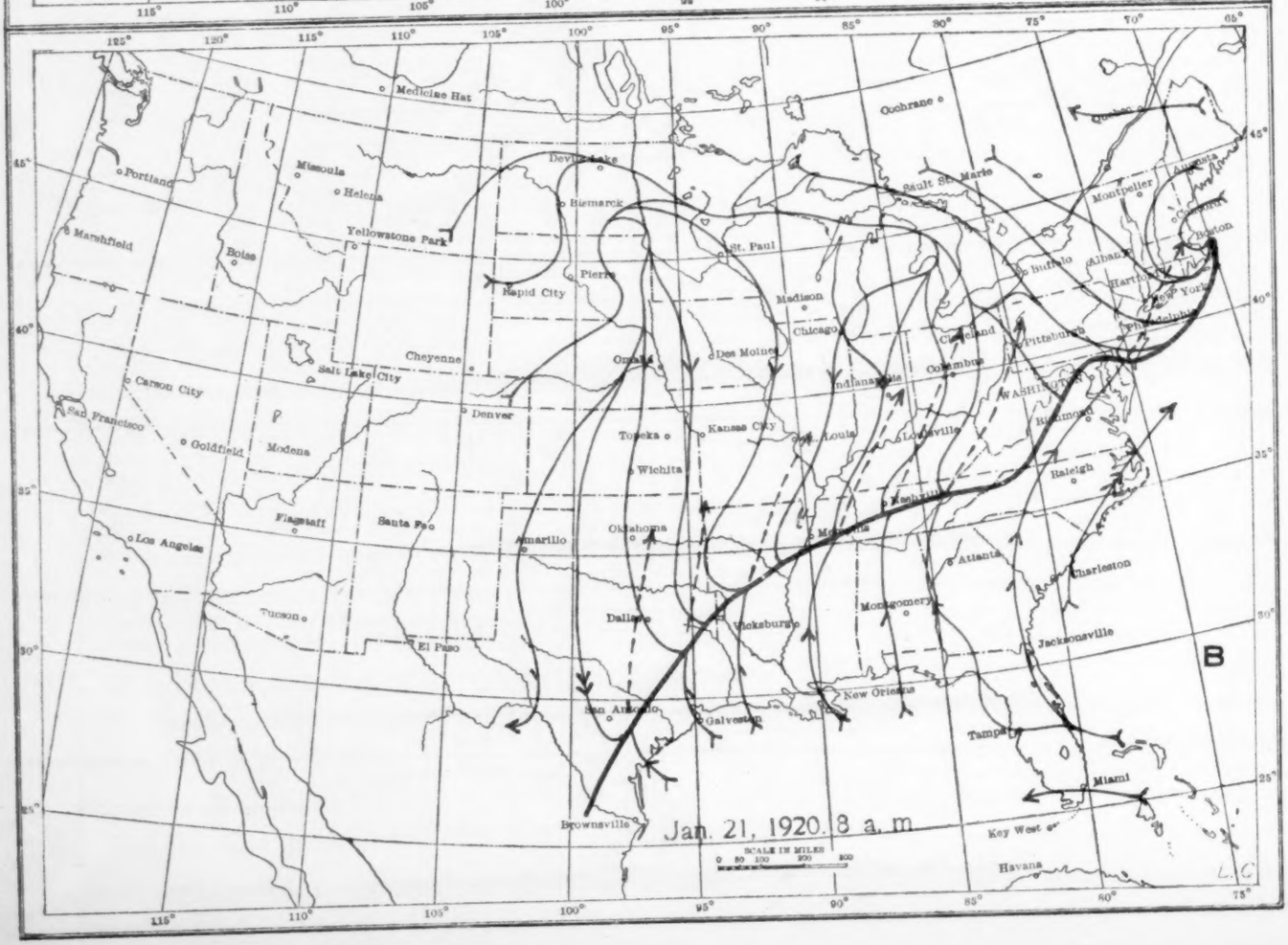
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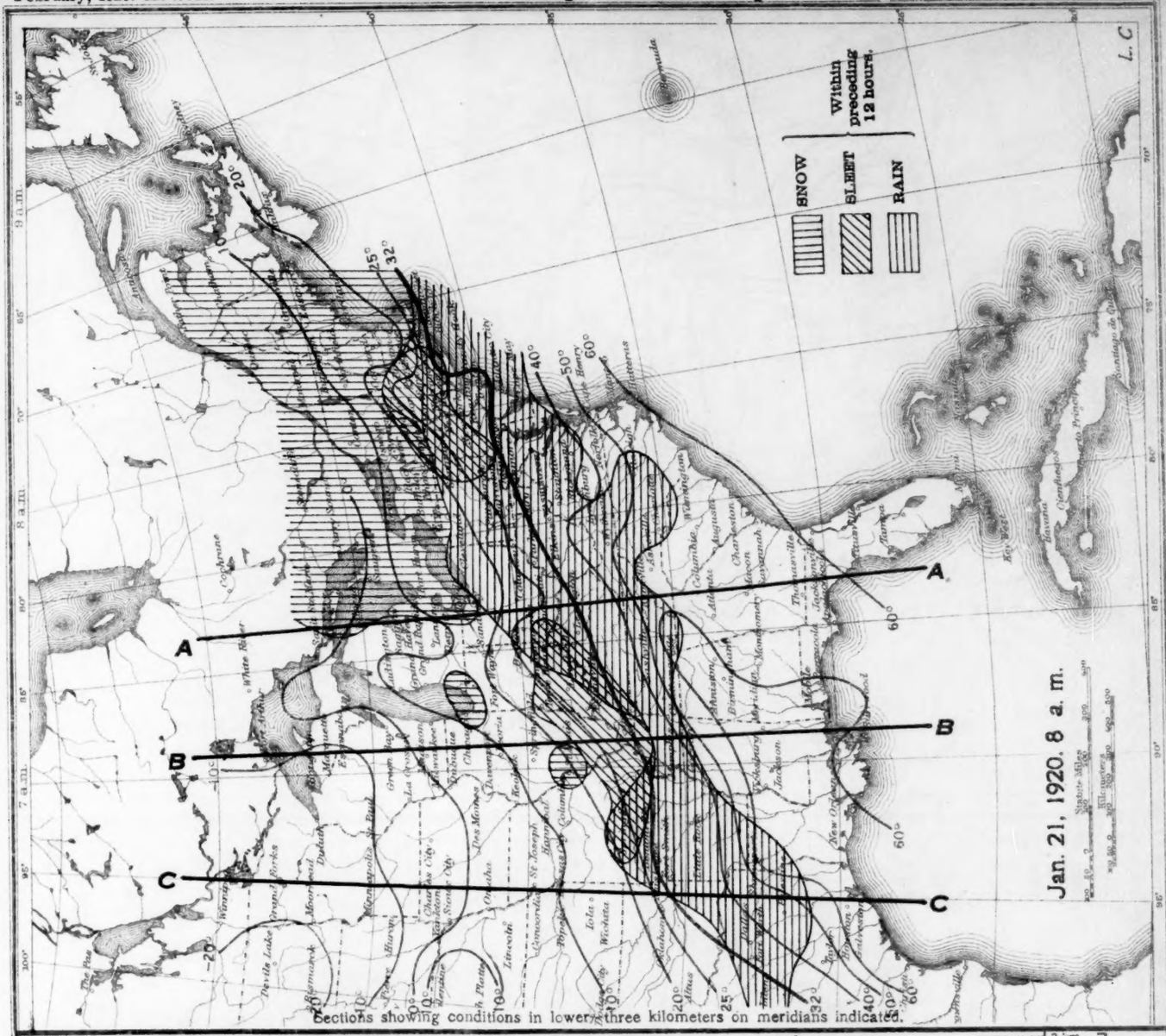

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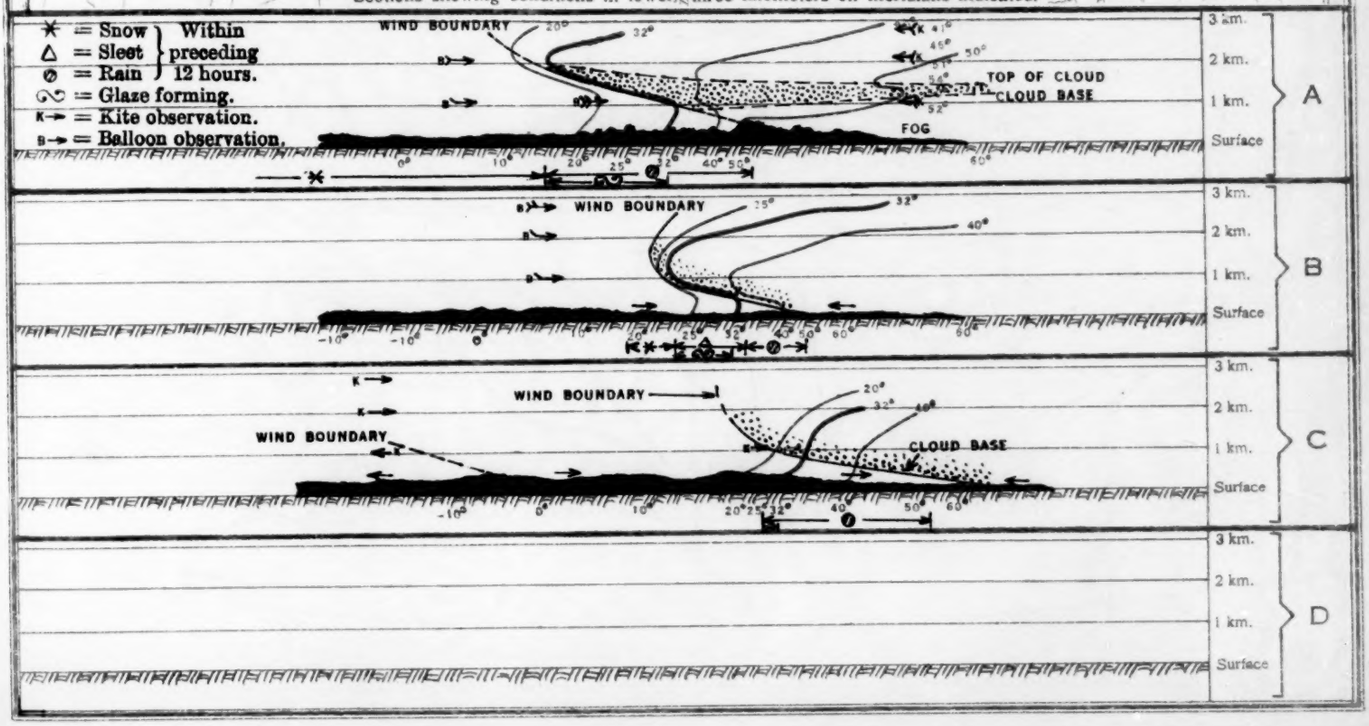

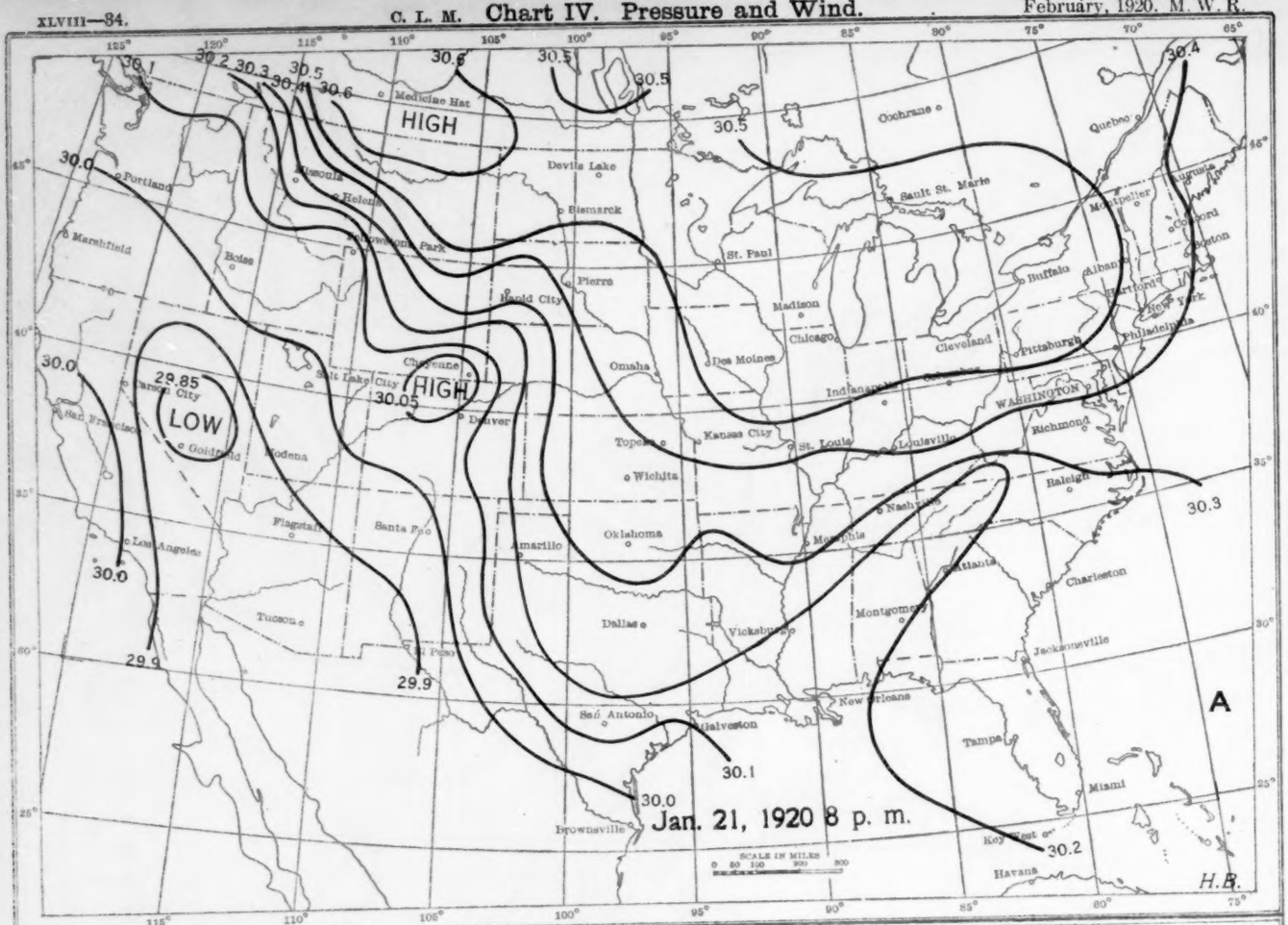
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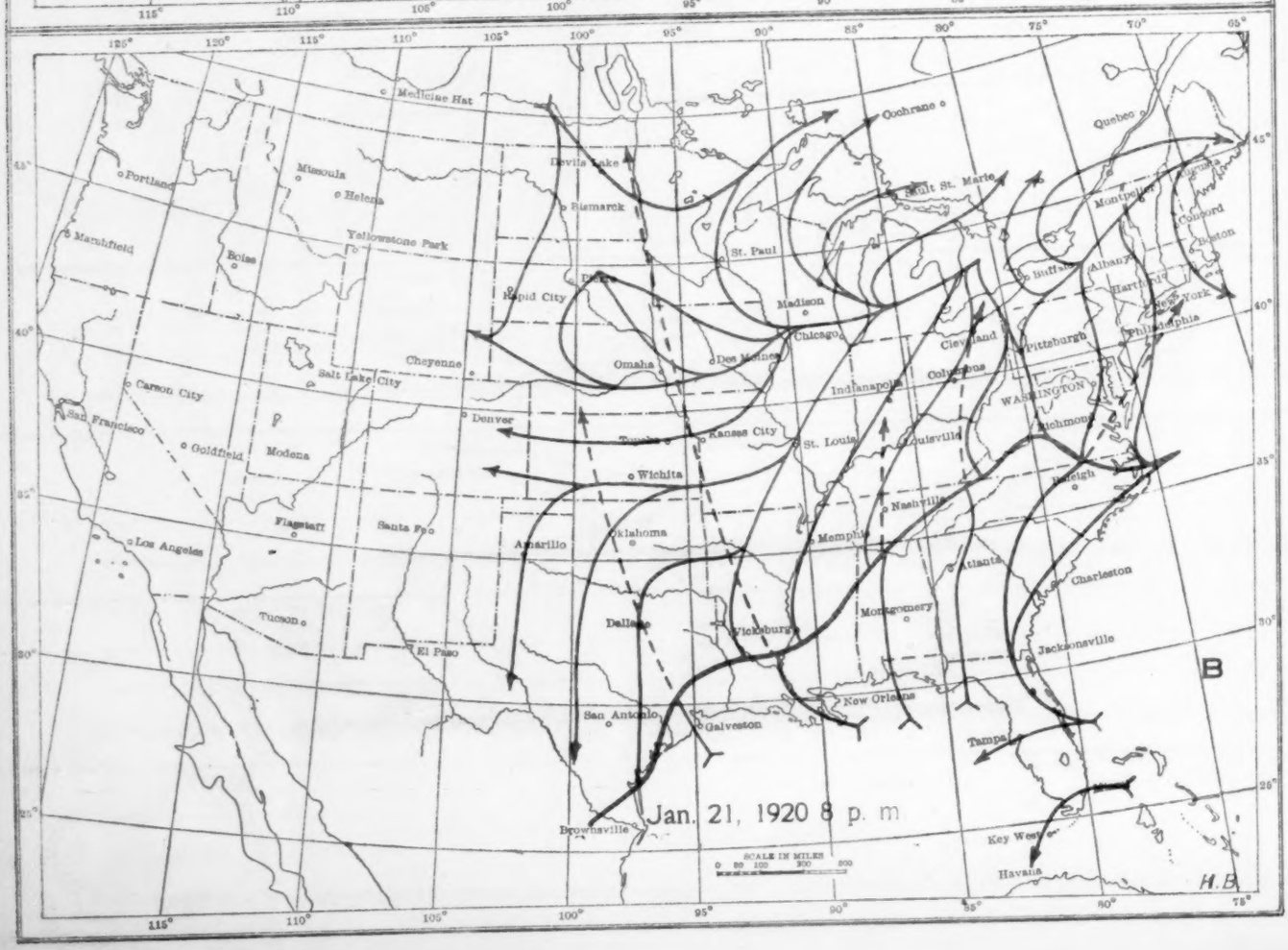
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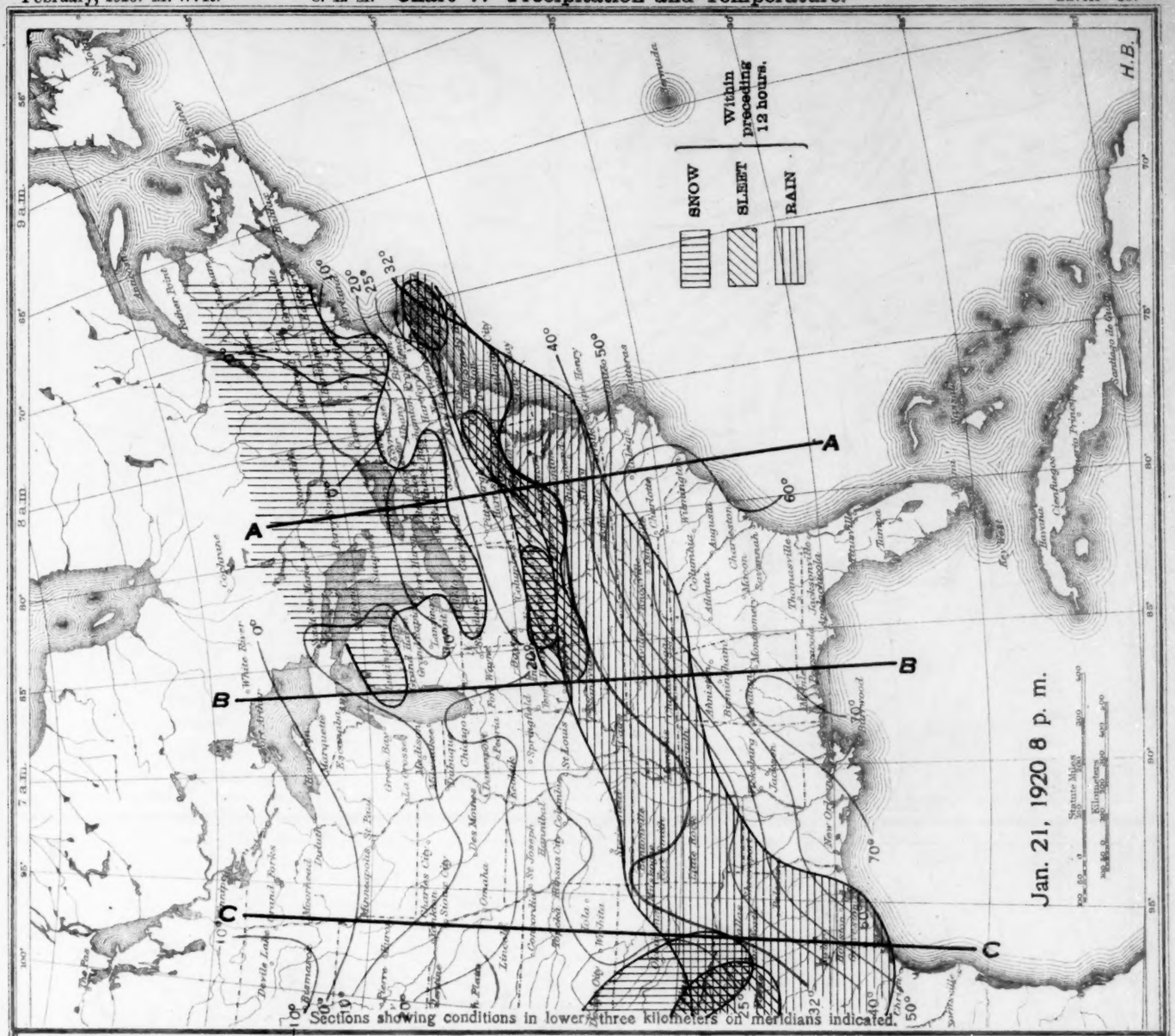

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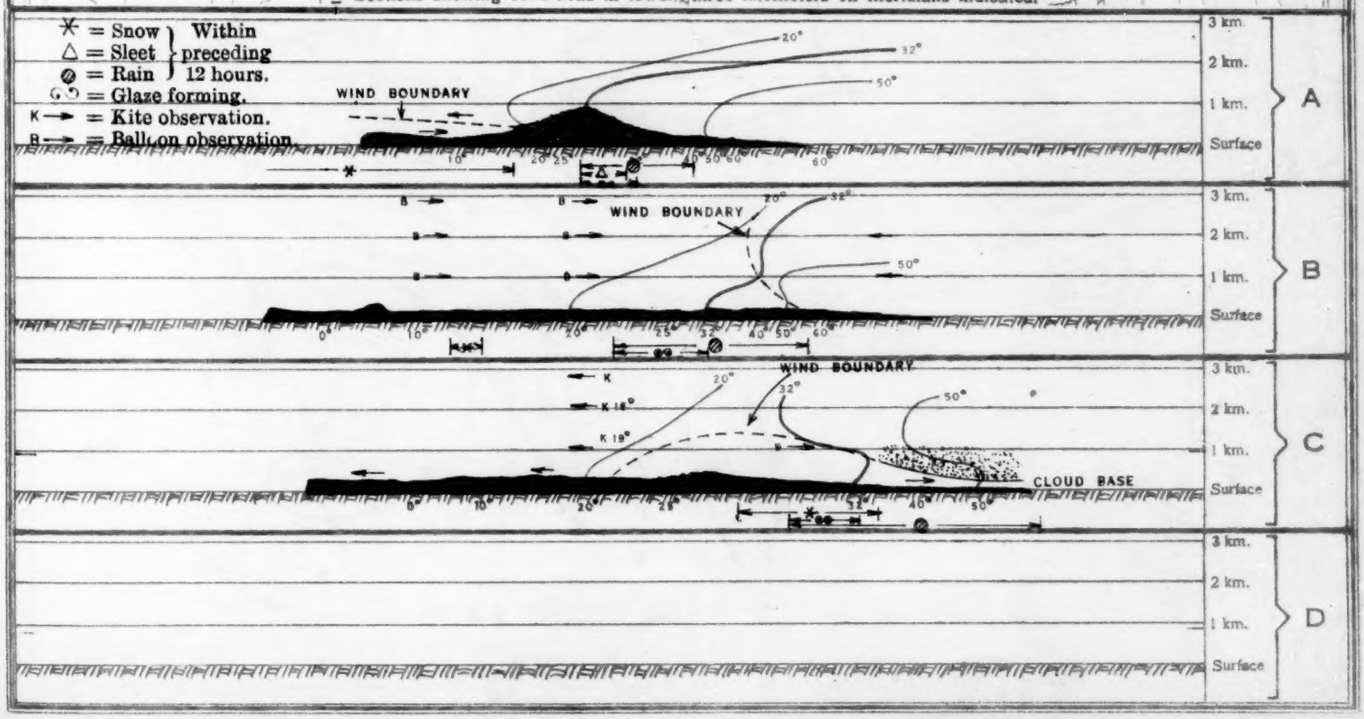

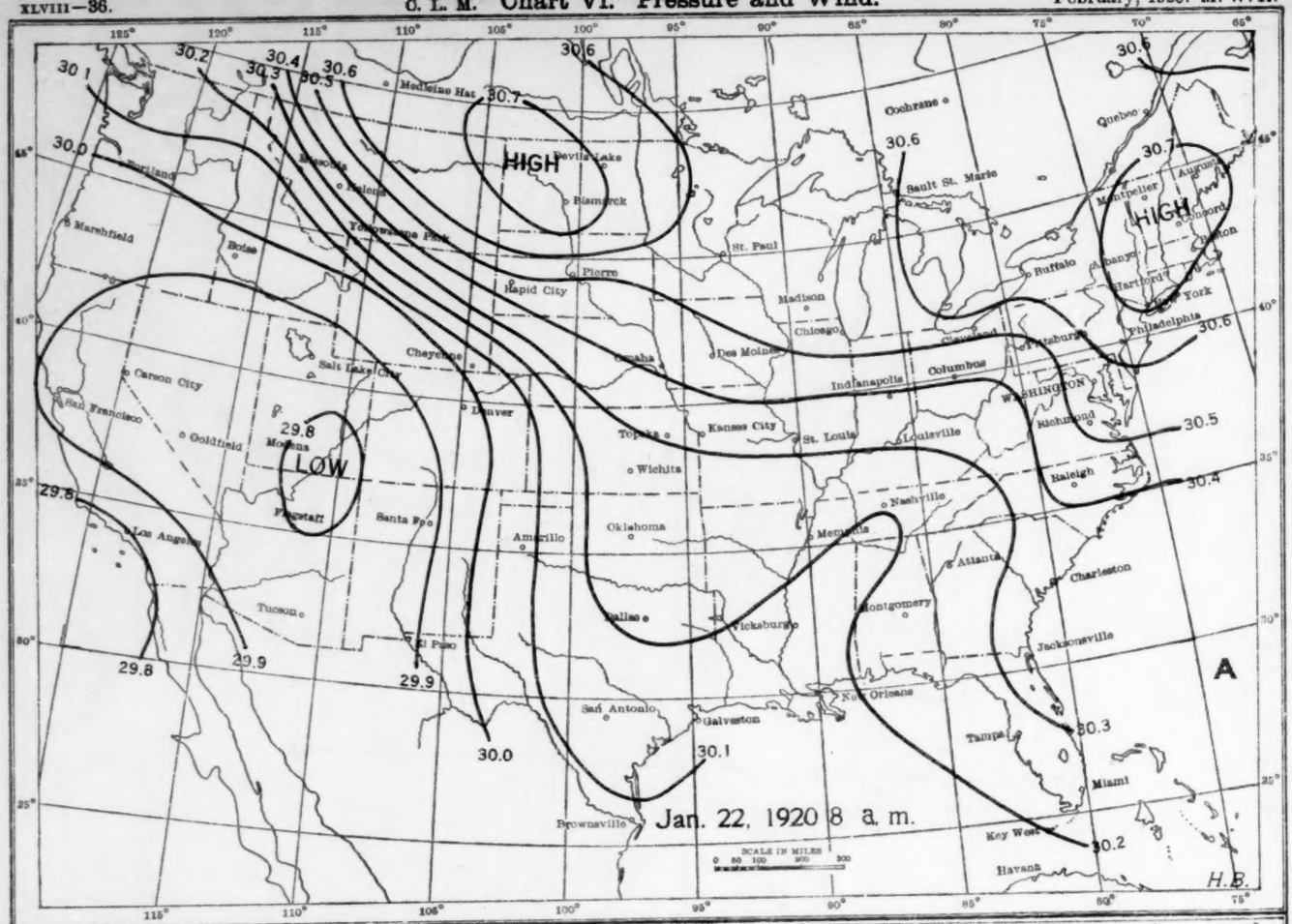
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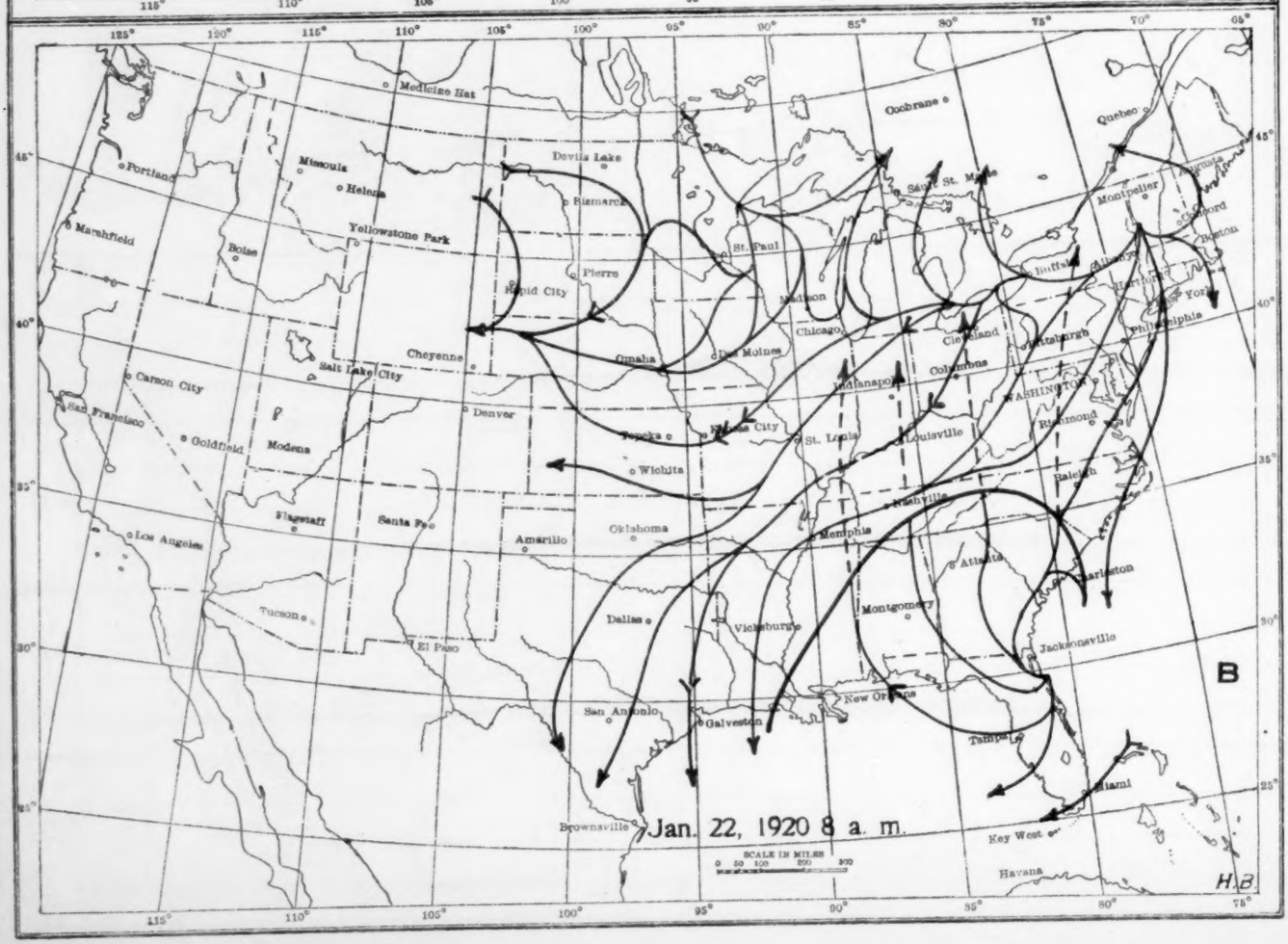
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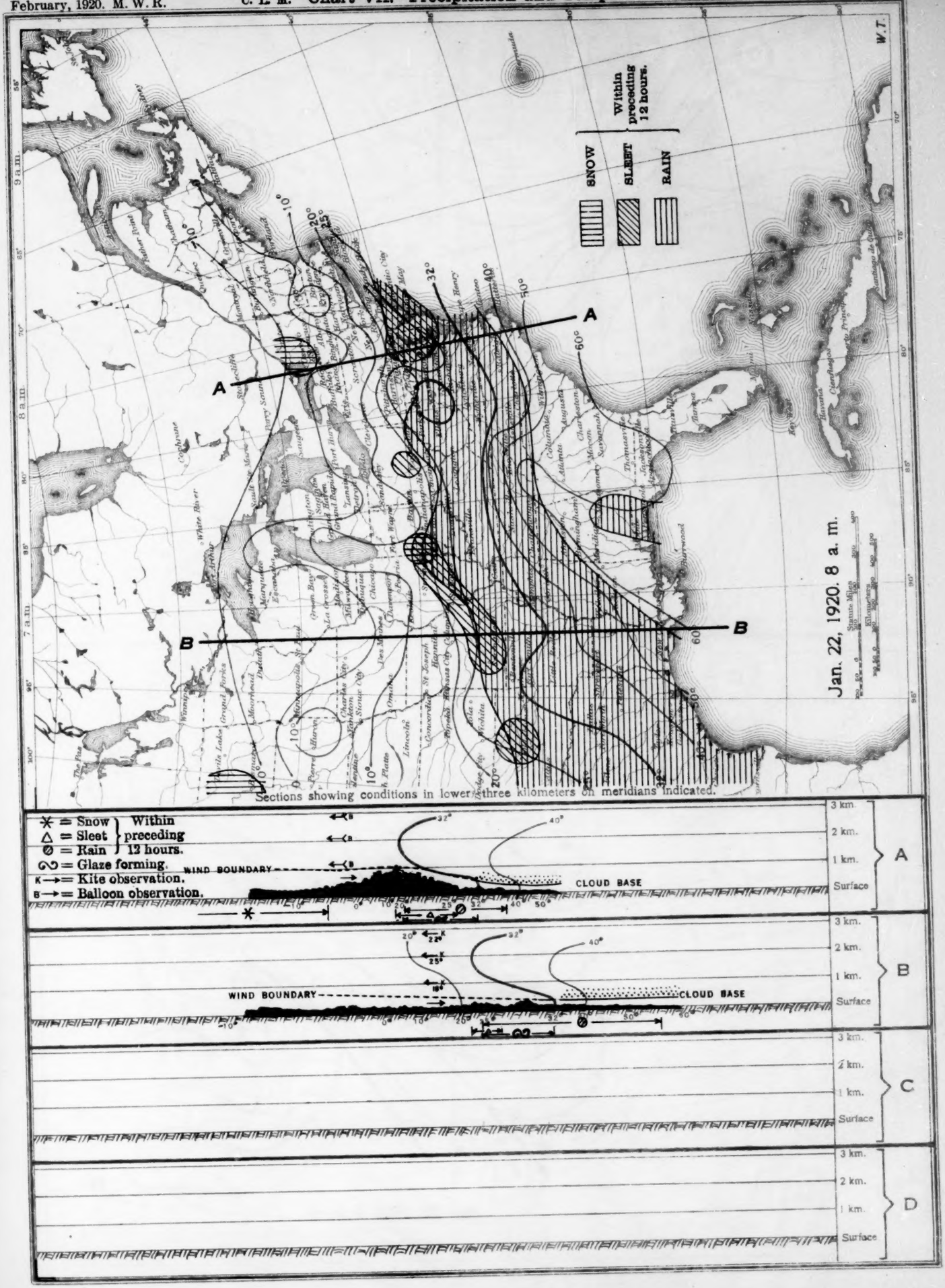
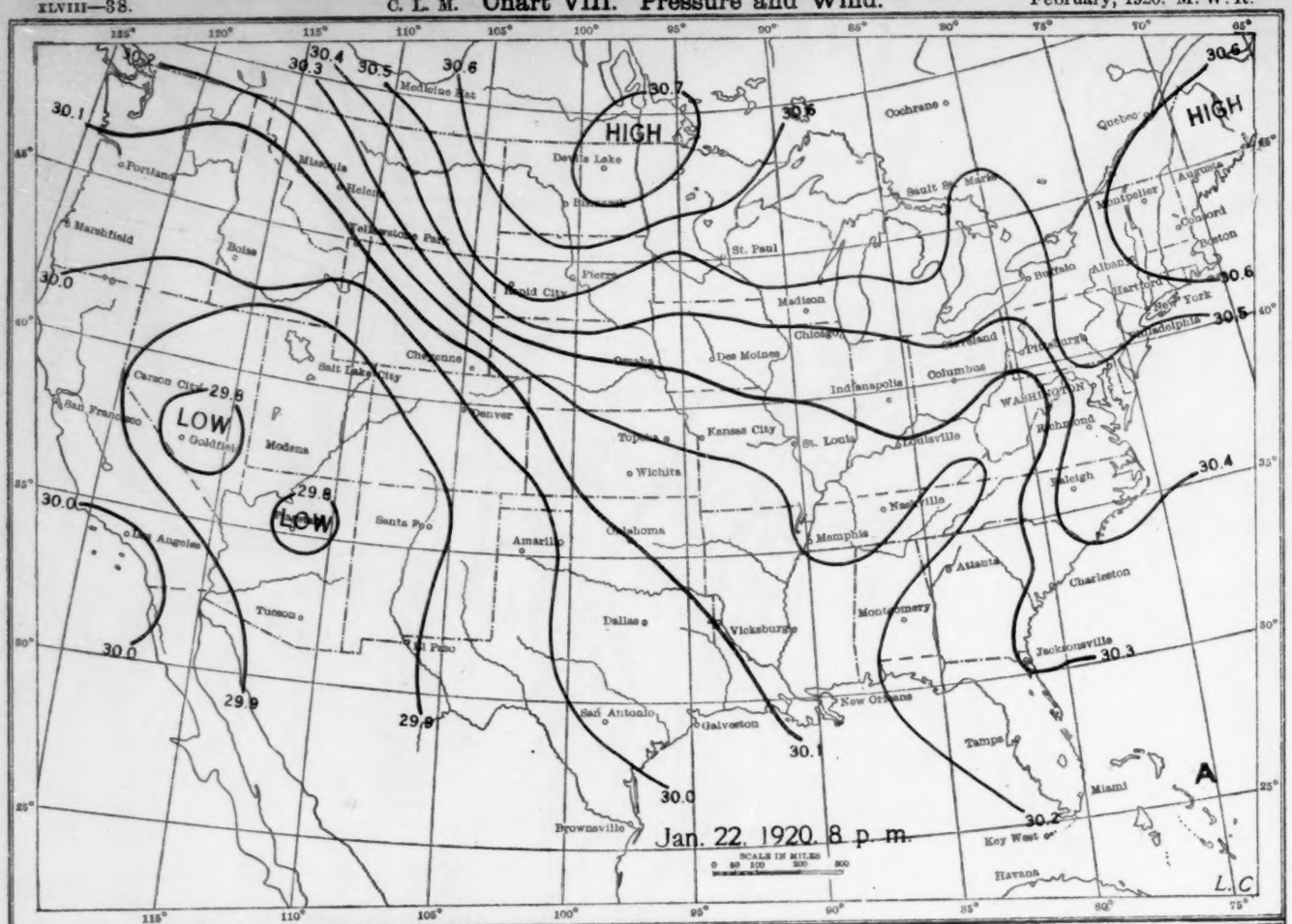

Within preceding 12 hours.
SNOW
SLEET
RAIN
W.T.
9 a.m.
8 a.m.
7 a.m.
A
B
Jan. 22, 1920. 8 a. m.
Statute Miles
Kilometers
Sections showing conditions in lower three kilometers on meridians indicated.
✳ = Snow
△ = Sleet
⌀ = Rain
Within preceding 12 hours.
= Glaze forming.
K→ = Kite observation.
B→ = Balloon observation.
WIND BOUNDARY
CLOUD BASE
3 km.
2 km.
1 km.
Surface
A
B
C
D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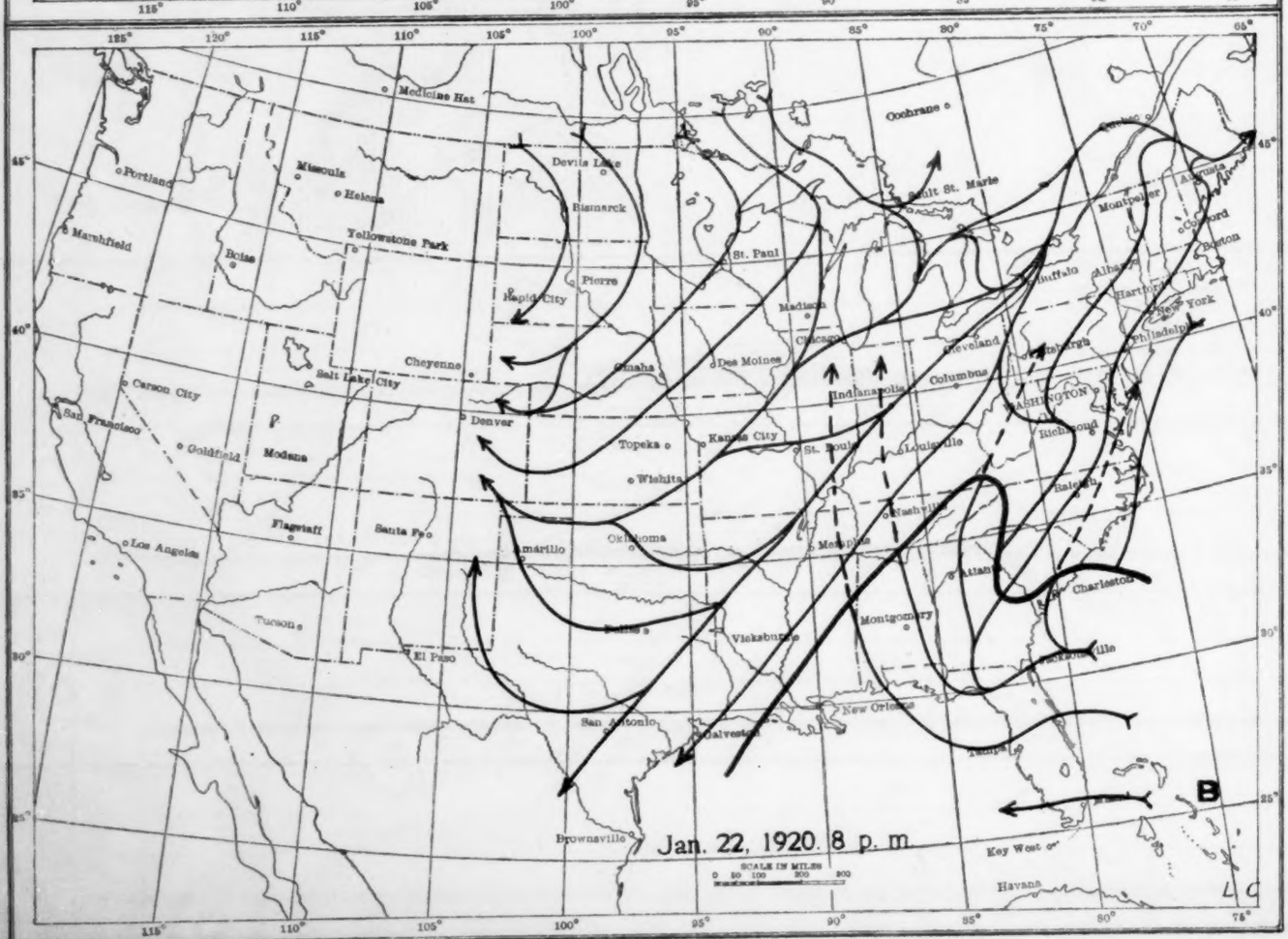
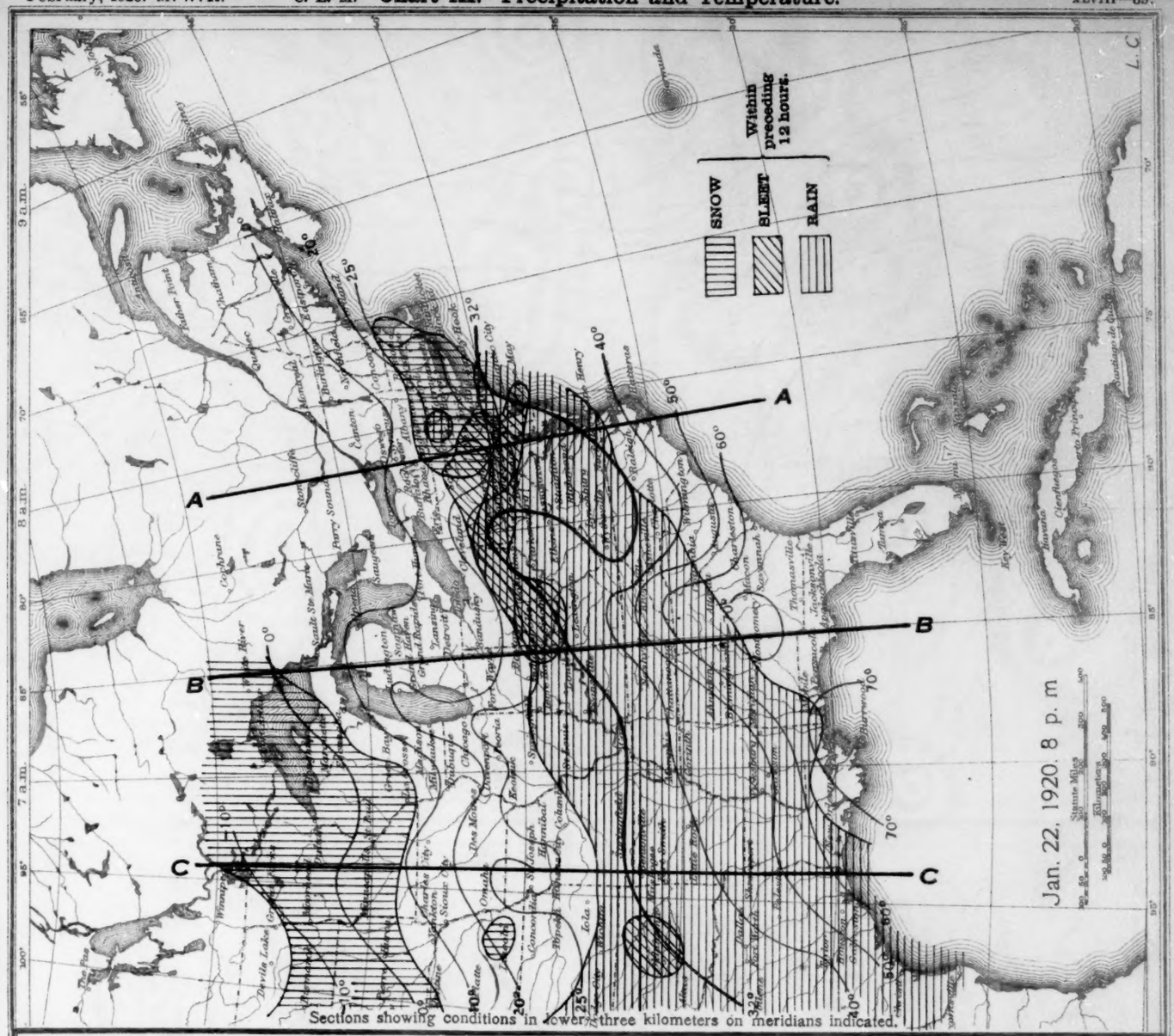
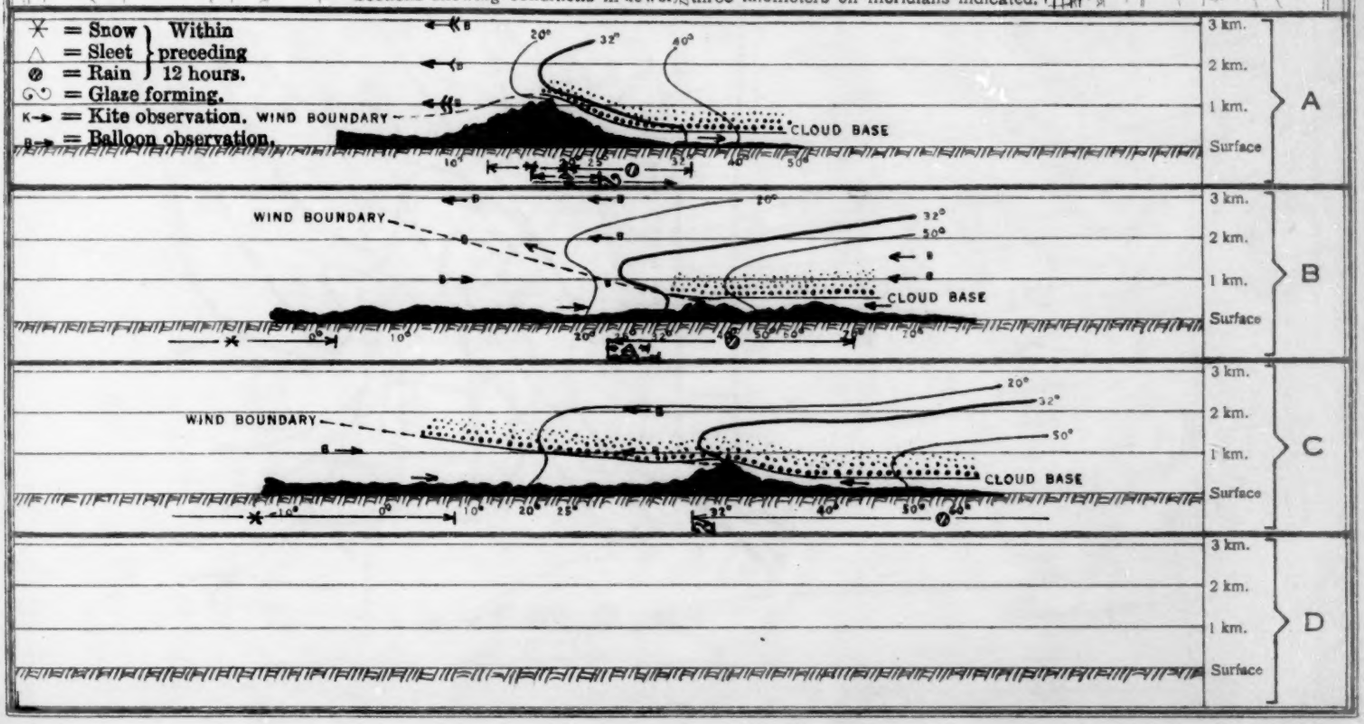
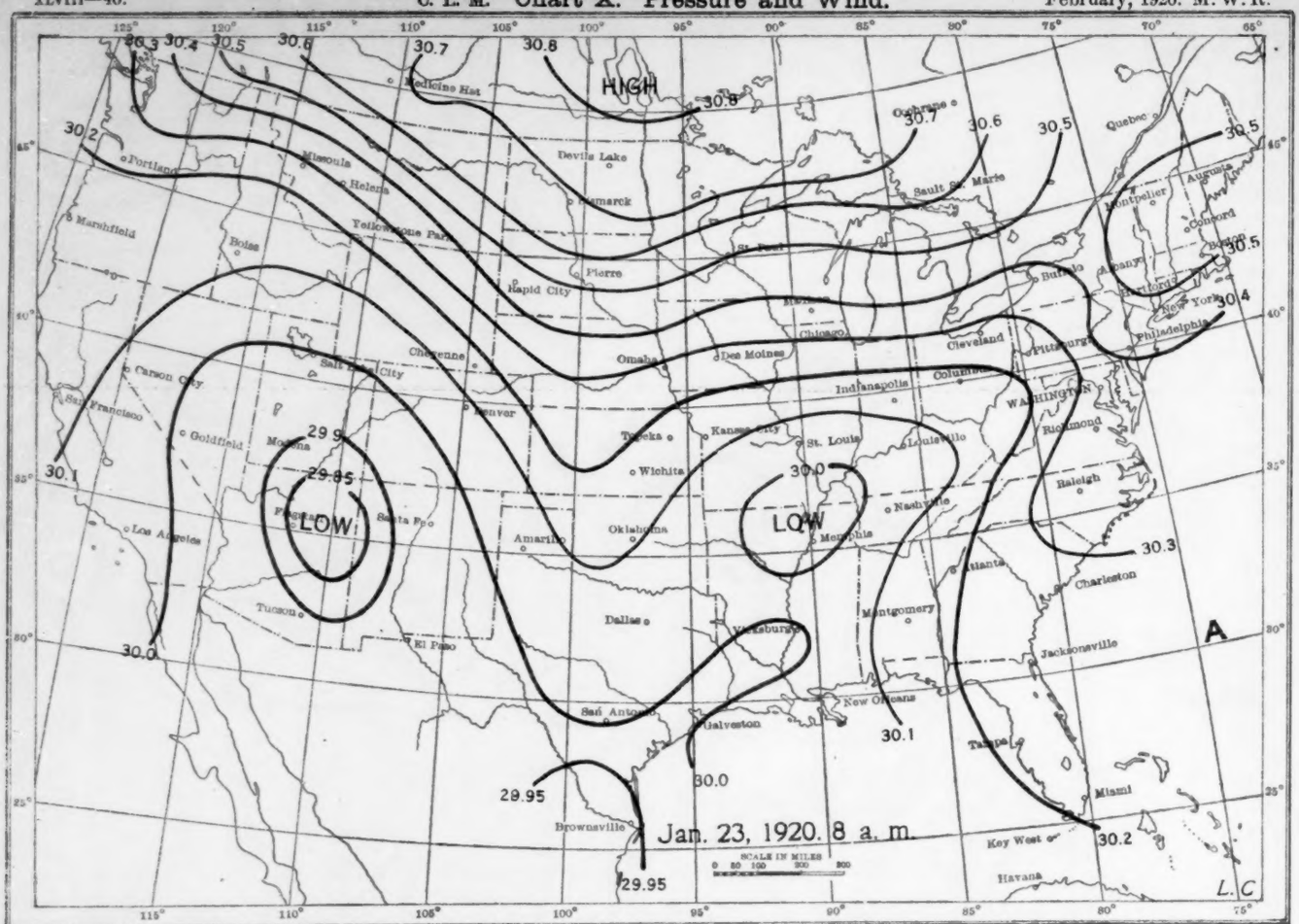
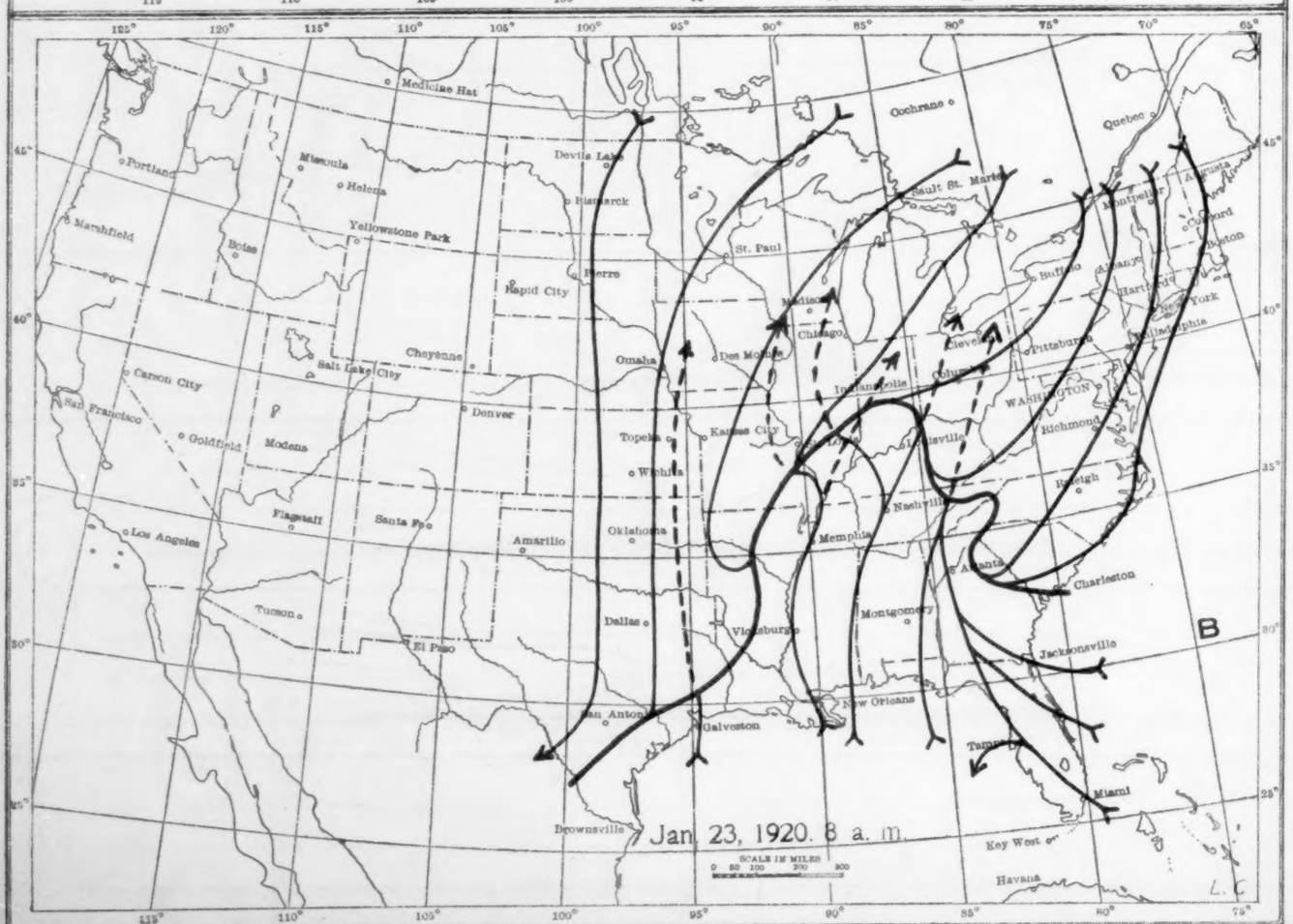
A
L. C

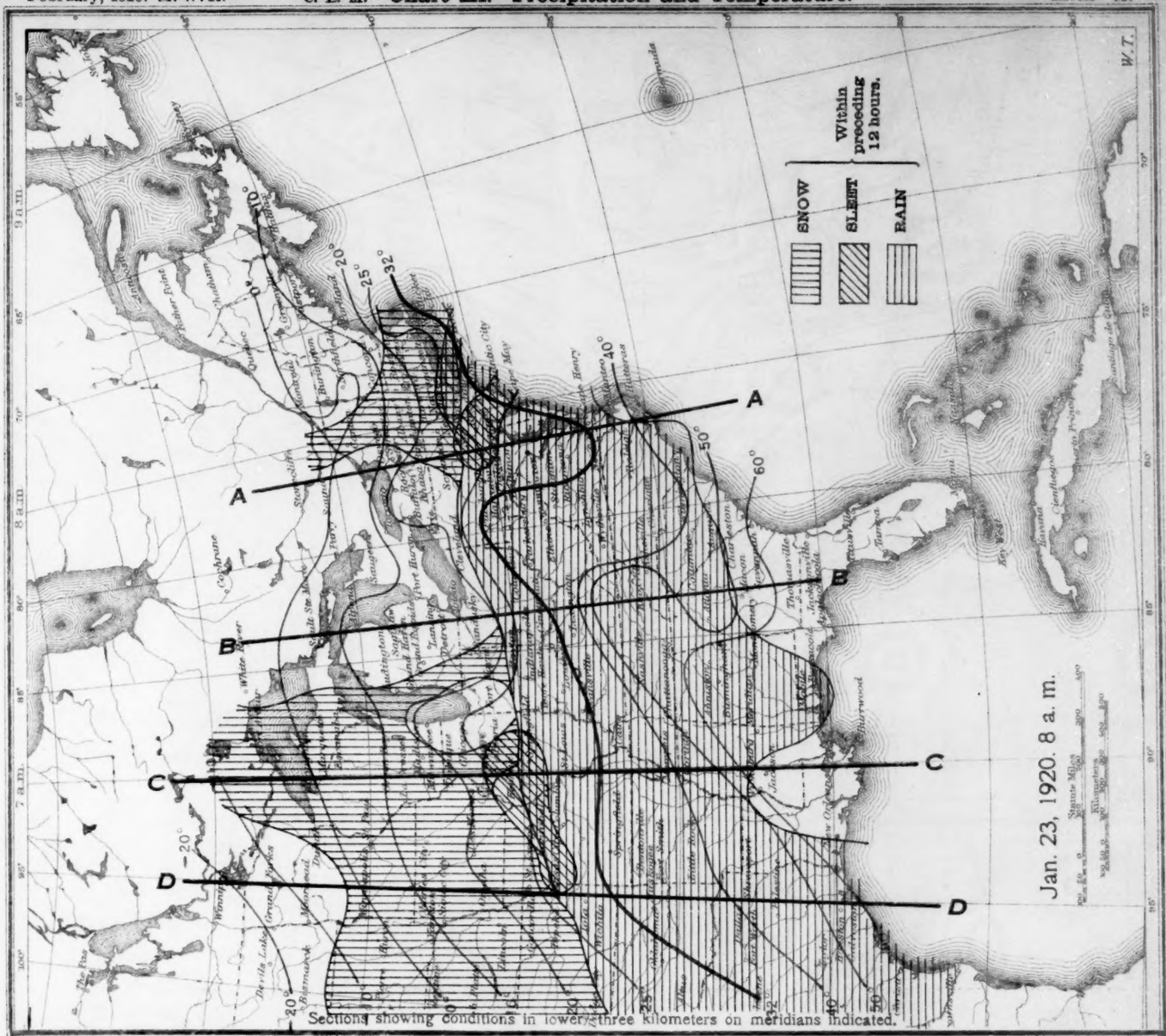

Jan. 22, 1920. 8 p. m.
B
L. C

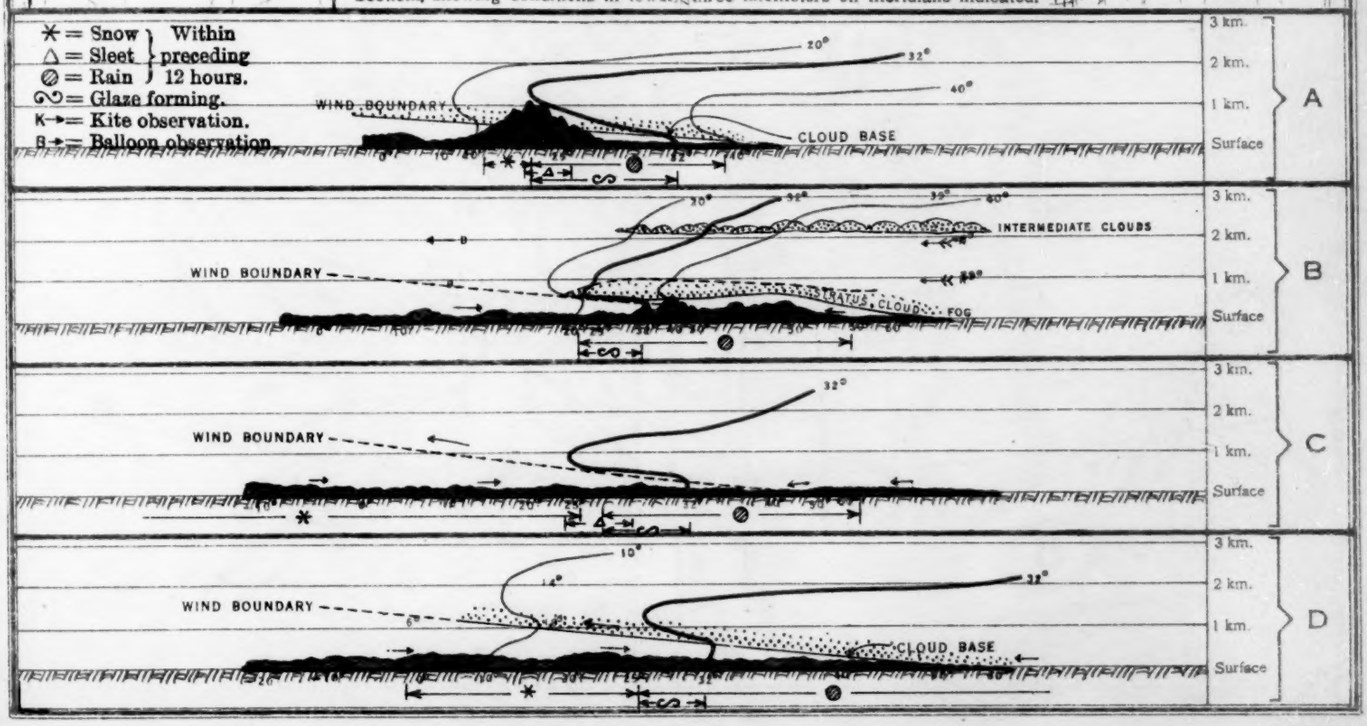

Within preceding 12 hours.
SNOW
SLEET
RAIN
A
B
C
Jan. 22, 1920. 8 p. m.
Sections showing conditions in lower three kilometers on meridians indicated.

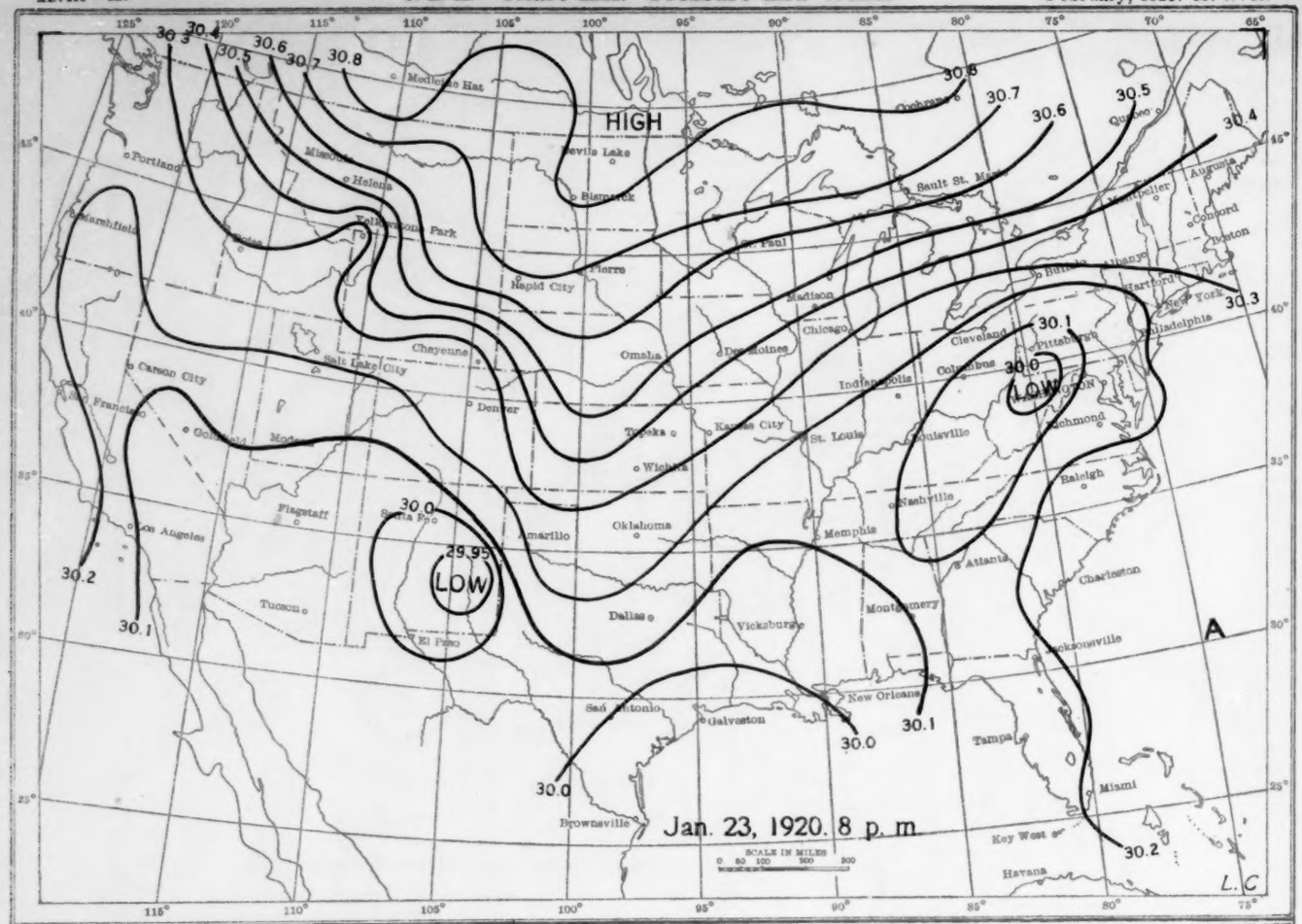

= Snow
= Sleet
= Rain
Within preceding 12 hours.
= Glaze forming.
= Kite observation.
= Balloon observation.
WIND BOUNDARY
CLOUD BASE
3 km.
2 km.
1 km.
Surface
A
B
C
D

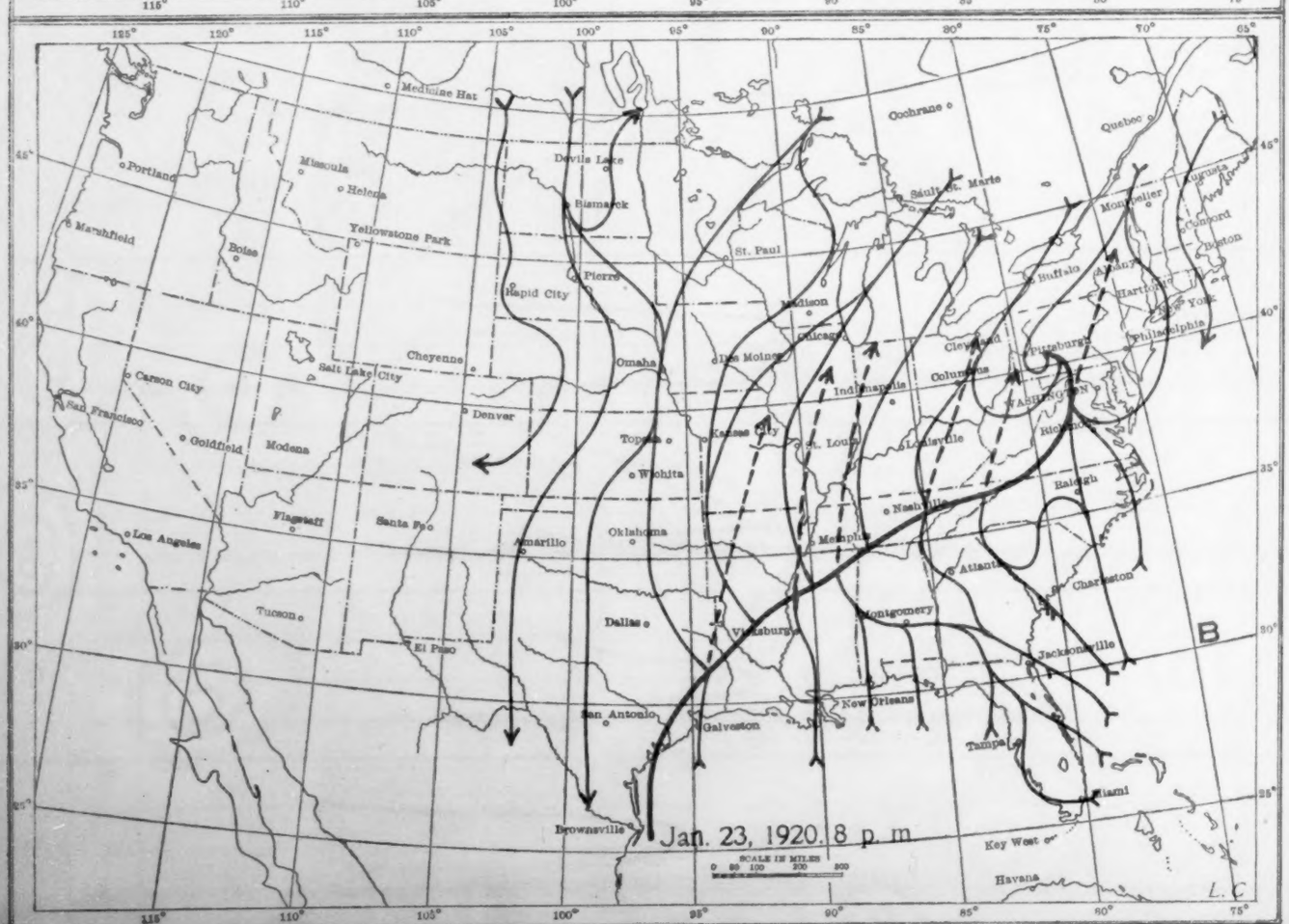

HIGH
LOW
LOW
30.8
30.7
30.6
30.5
30.4
30.3
30.2
30.1
30.0
29.95
29.9
29.85
A
Jan. 23, 1920. 8 a. m.
SCALE IN MILES
L. C

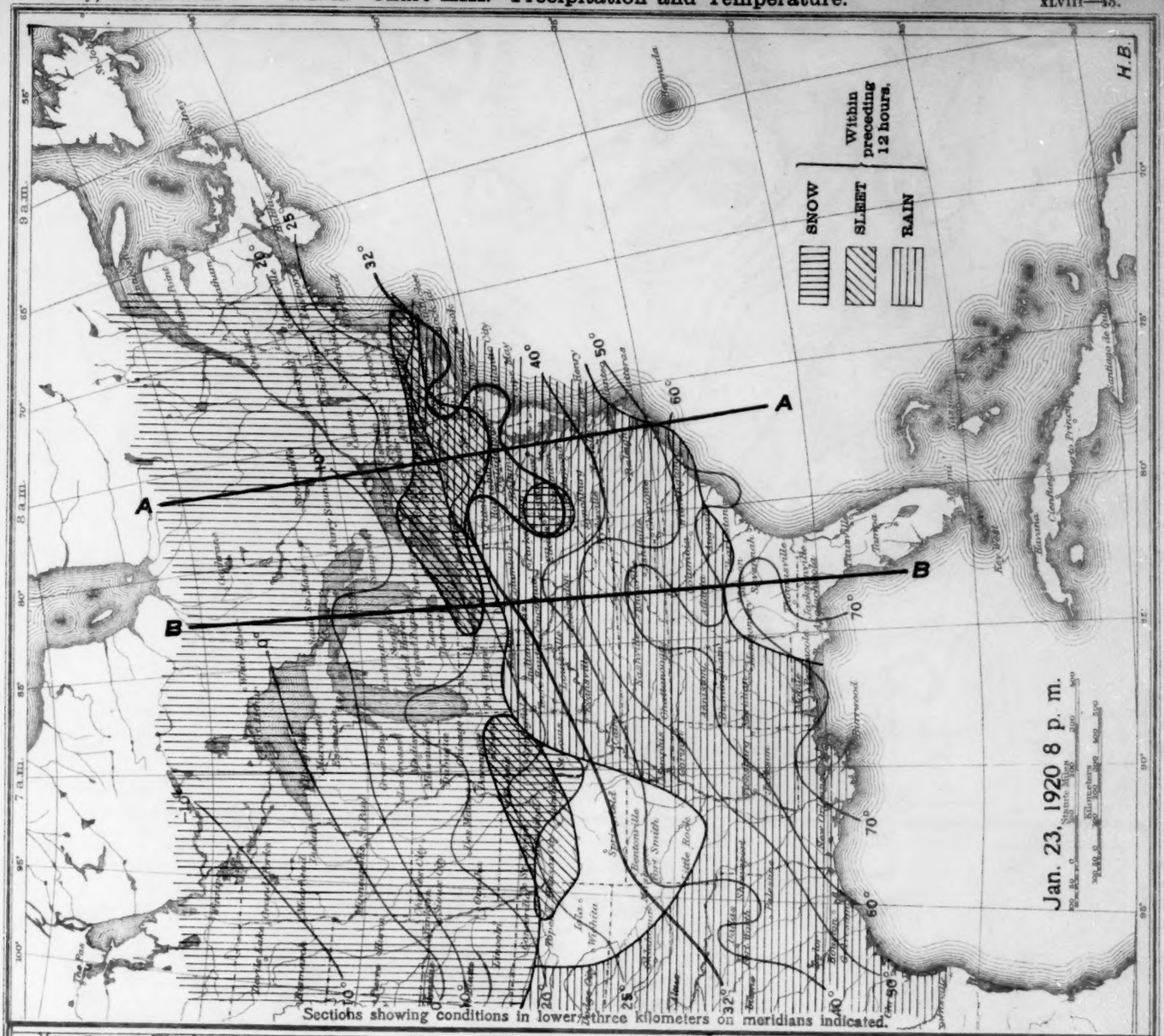

B
Jan. 23, 1920. 8 a. m.
SCALE IN MILES
L. C


W.T.
Within preceding 12 hours.
SNOW
SLEET
RAIN
A
B
C
D
Jan. 23, 1920. 8 a. m.
Sections showing conditions in lower three kilometers on meridians indicated.

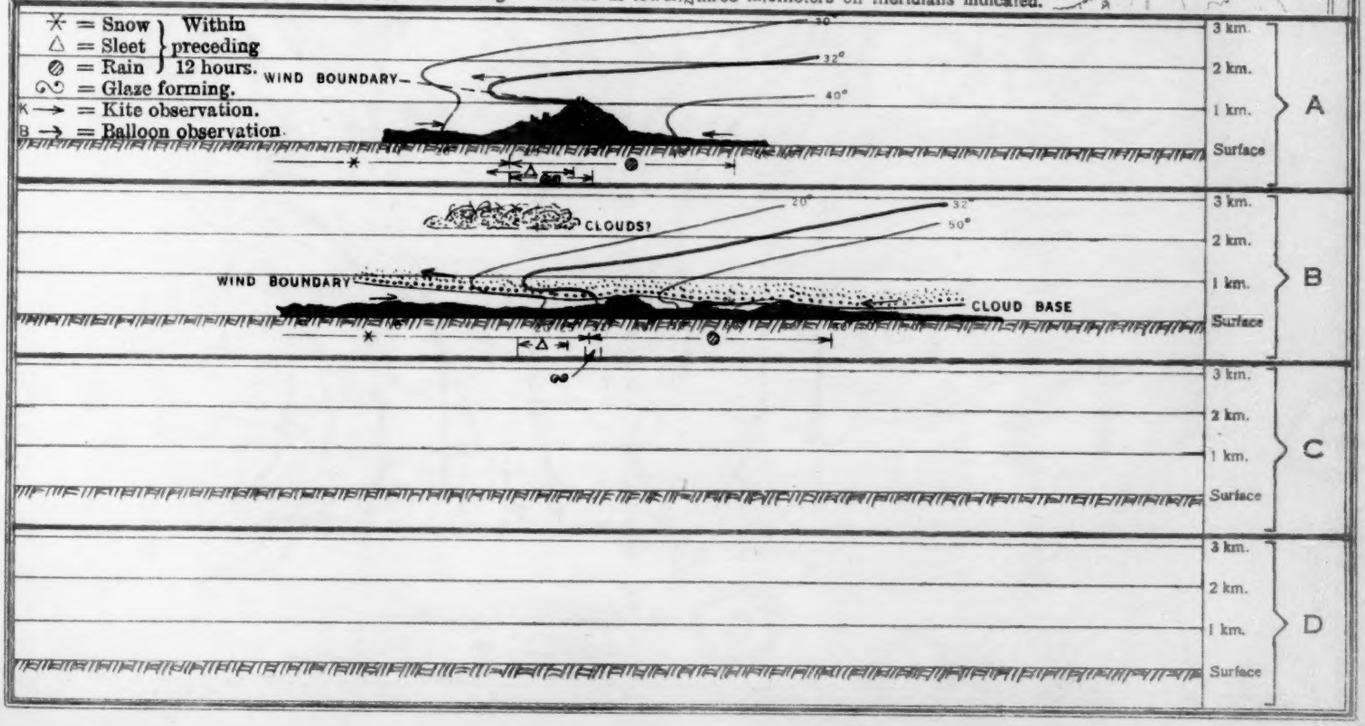

✳ = Snow
△ = Sleet
▨ = Rain
Within preceding 12 hours.
Glaze forming.
K→ = Kite observation.
B→ = Balloon observation.
WIND BOUNDARY
CLOUD BASE
INTERMEDIATE CLOUDS
STRATUS CLOUD
FOG
3 km.
2 km.
1 km.
Surface
A
B
C
D

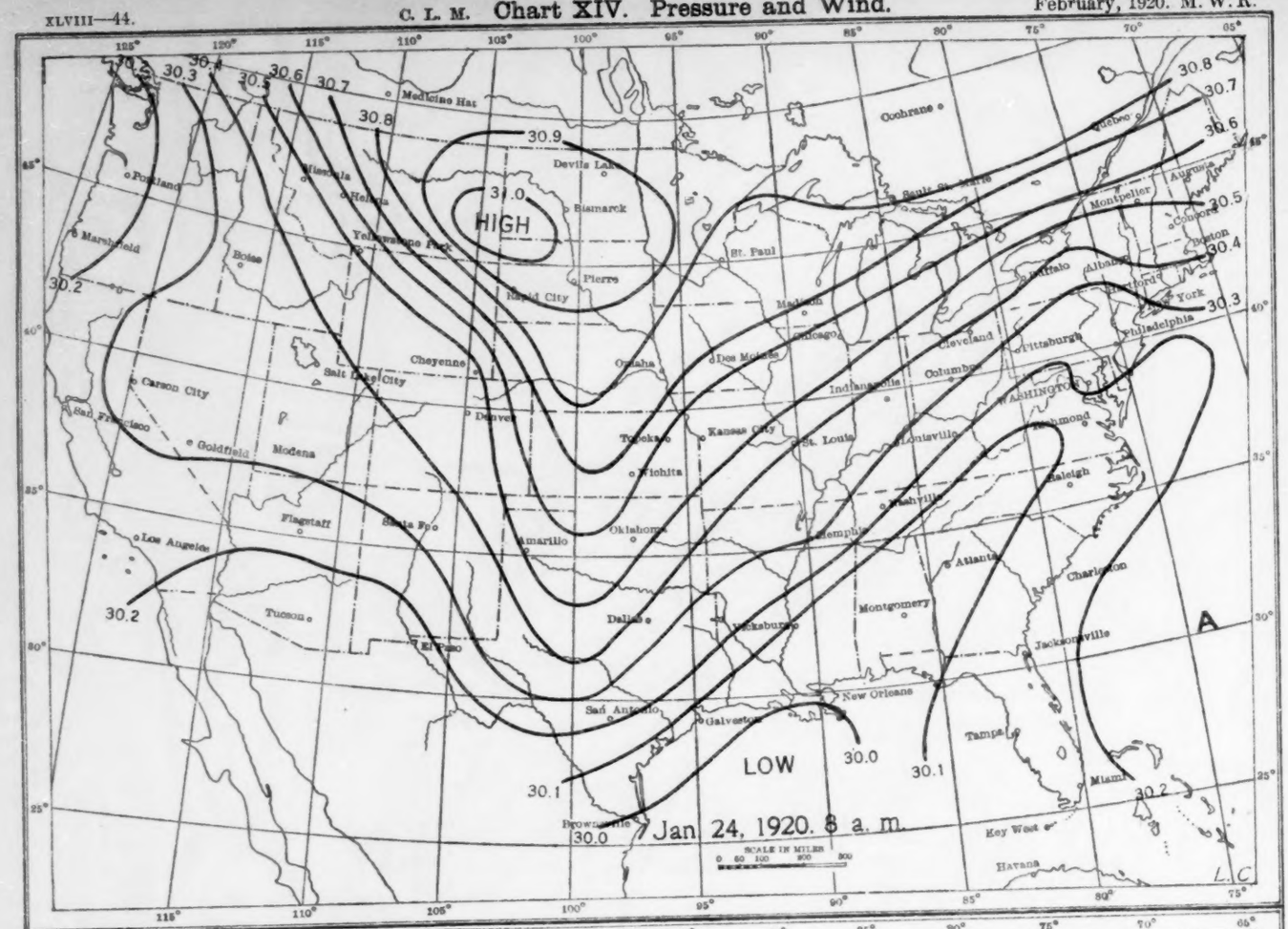

HIGH
LOW
LOW
30.0
29.95
30.1
30.2
30.3
30.4
30.5
30.6
30.7
30.8
Jan. 23, 1920. 8 p. m.
A
L. C

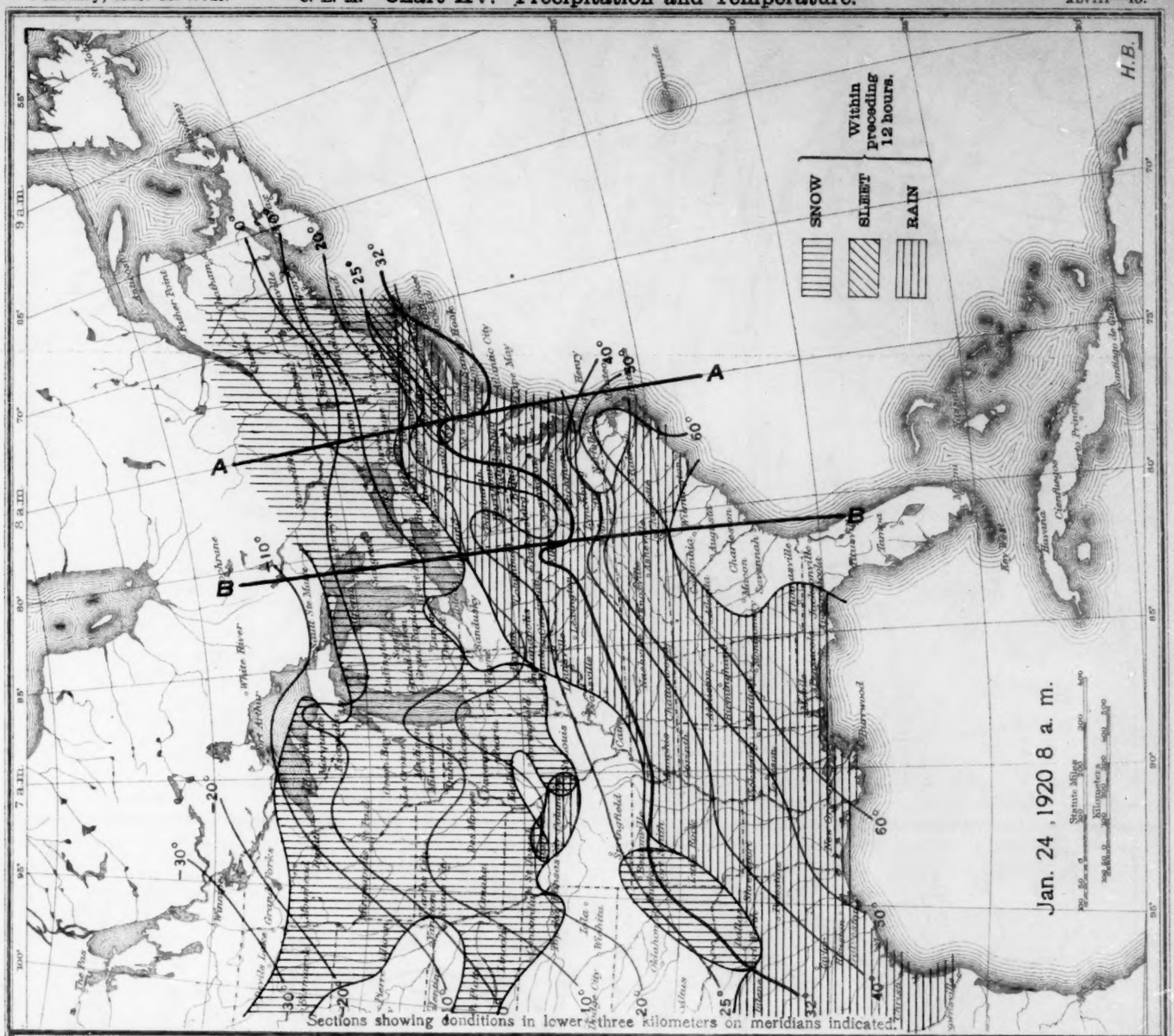

Jan. 23, 1920. 8 p. m.
B
L. C

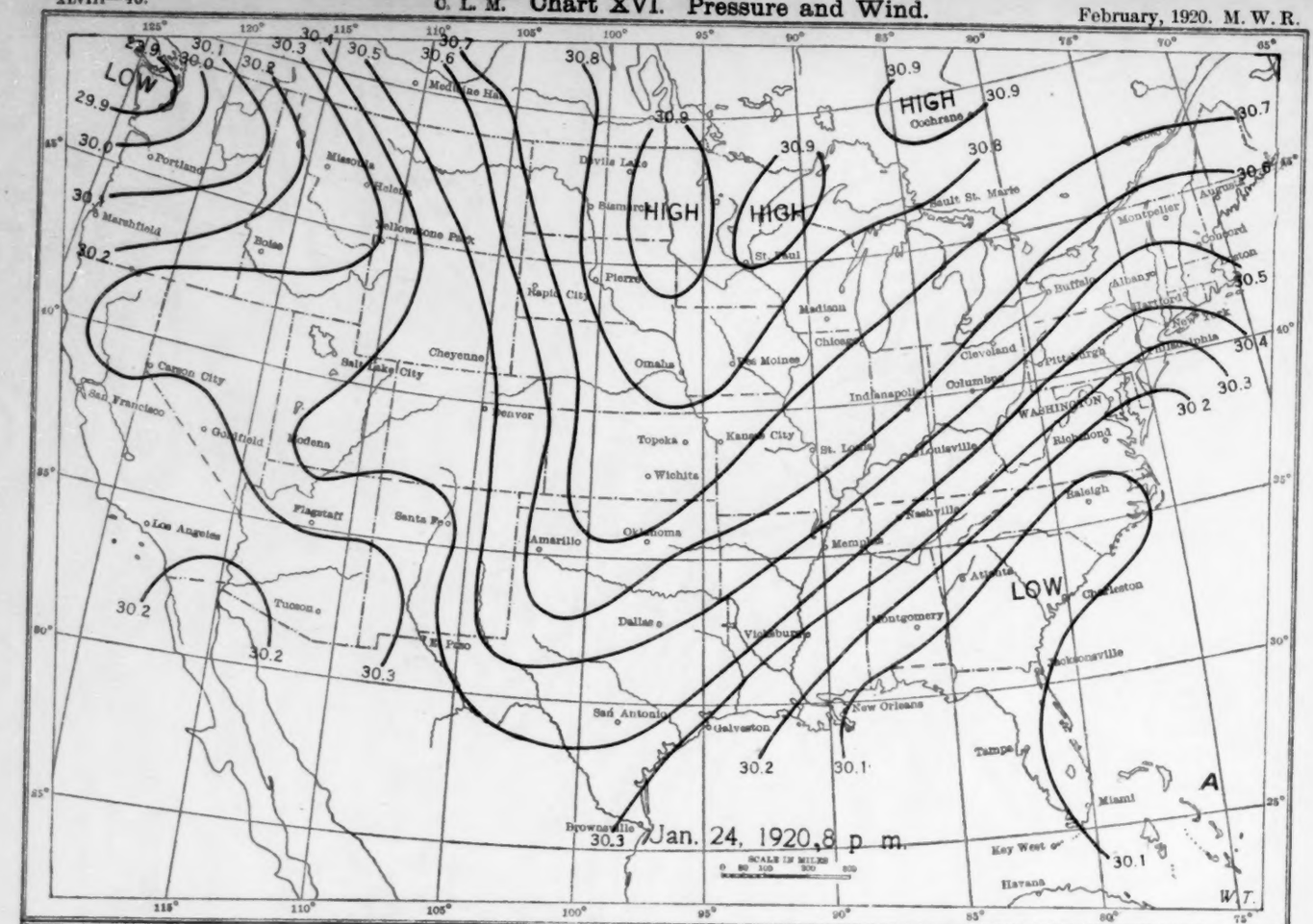


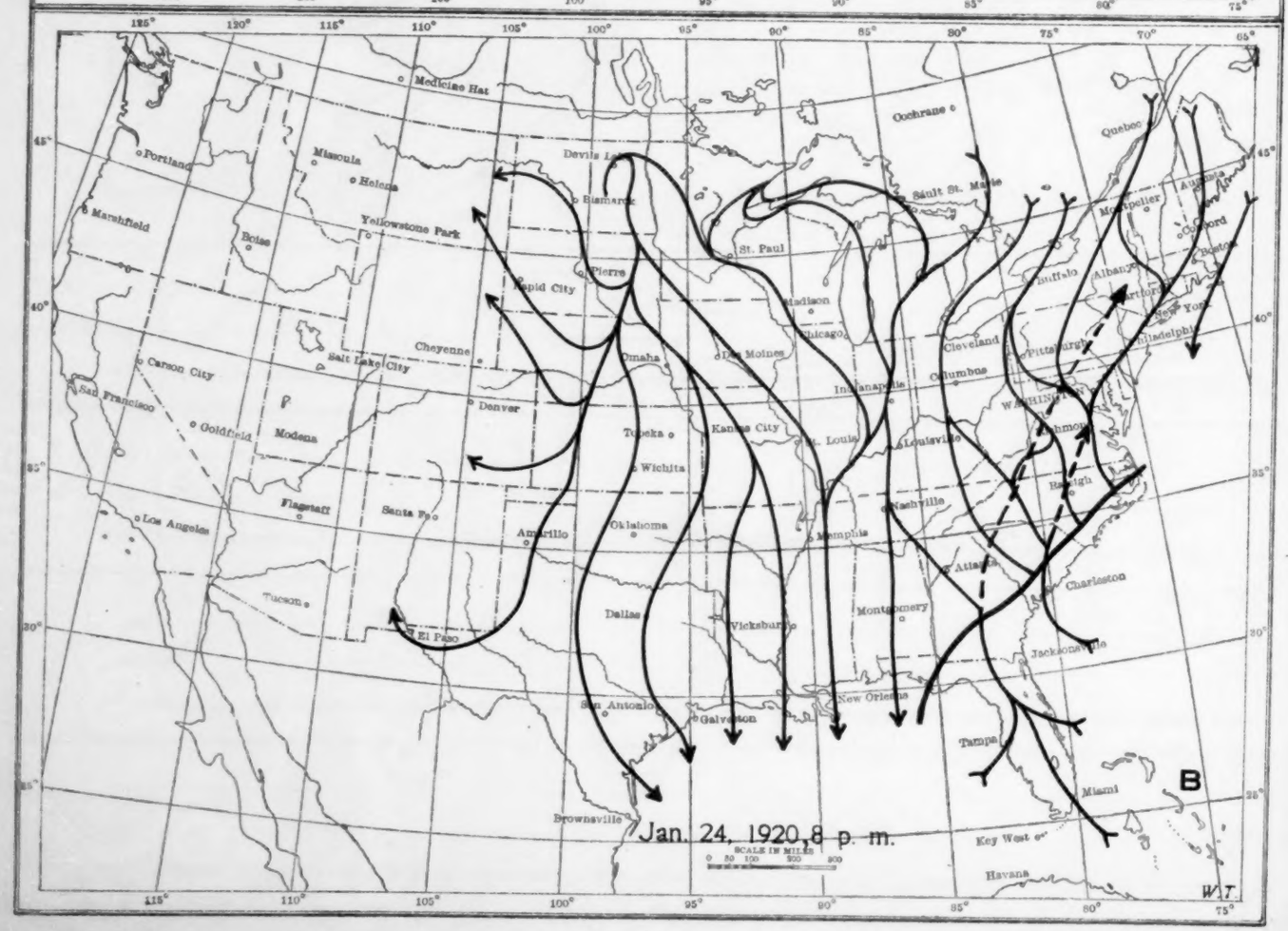
= Snow
= Sleet
= Rain
} Within preceding 12 hours.
= Glaze forming.
= Kite observation.
= Balloon observation.

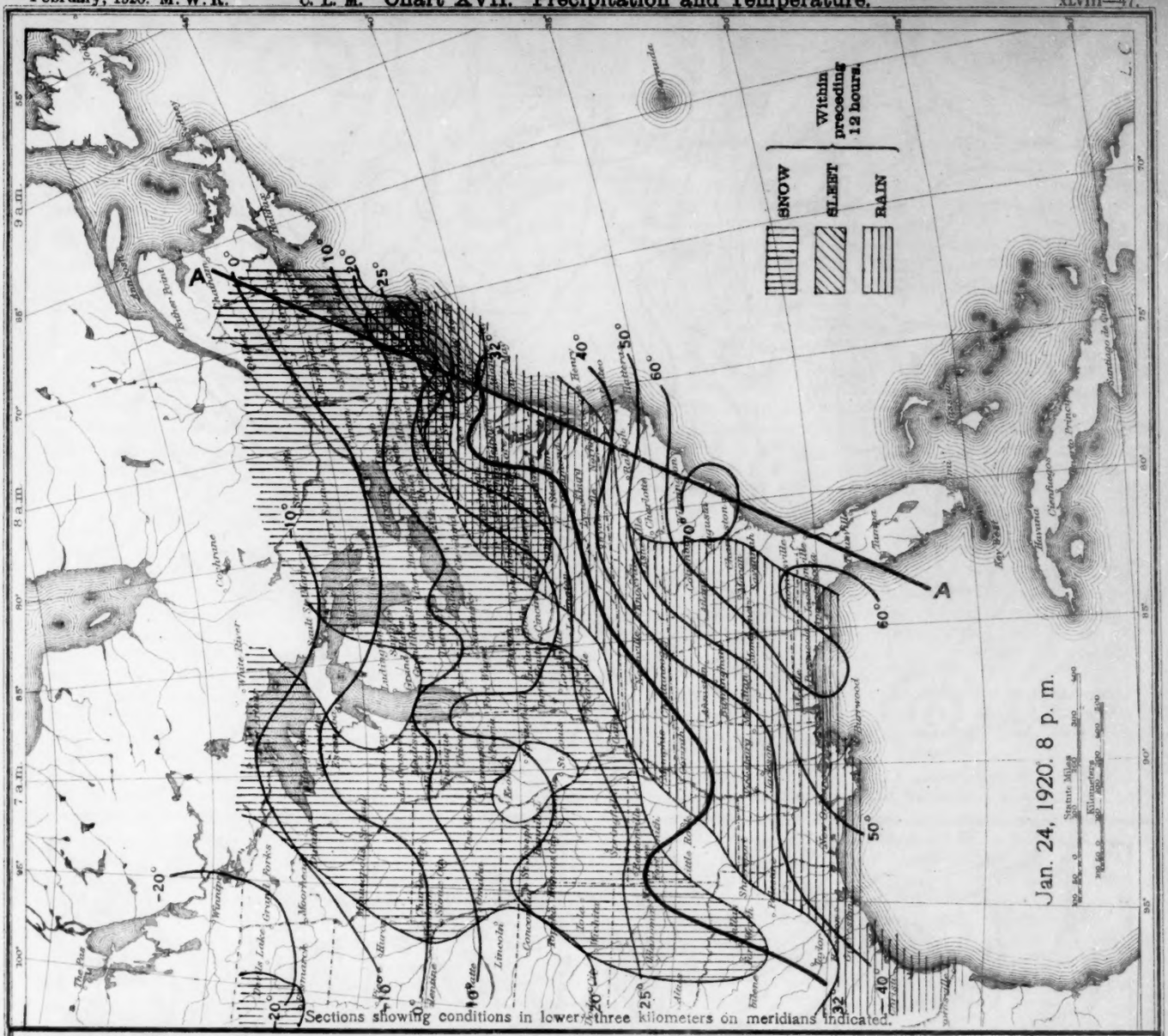


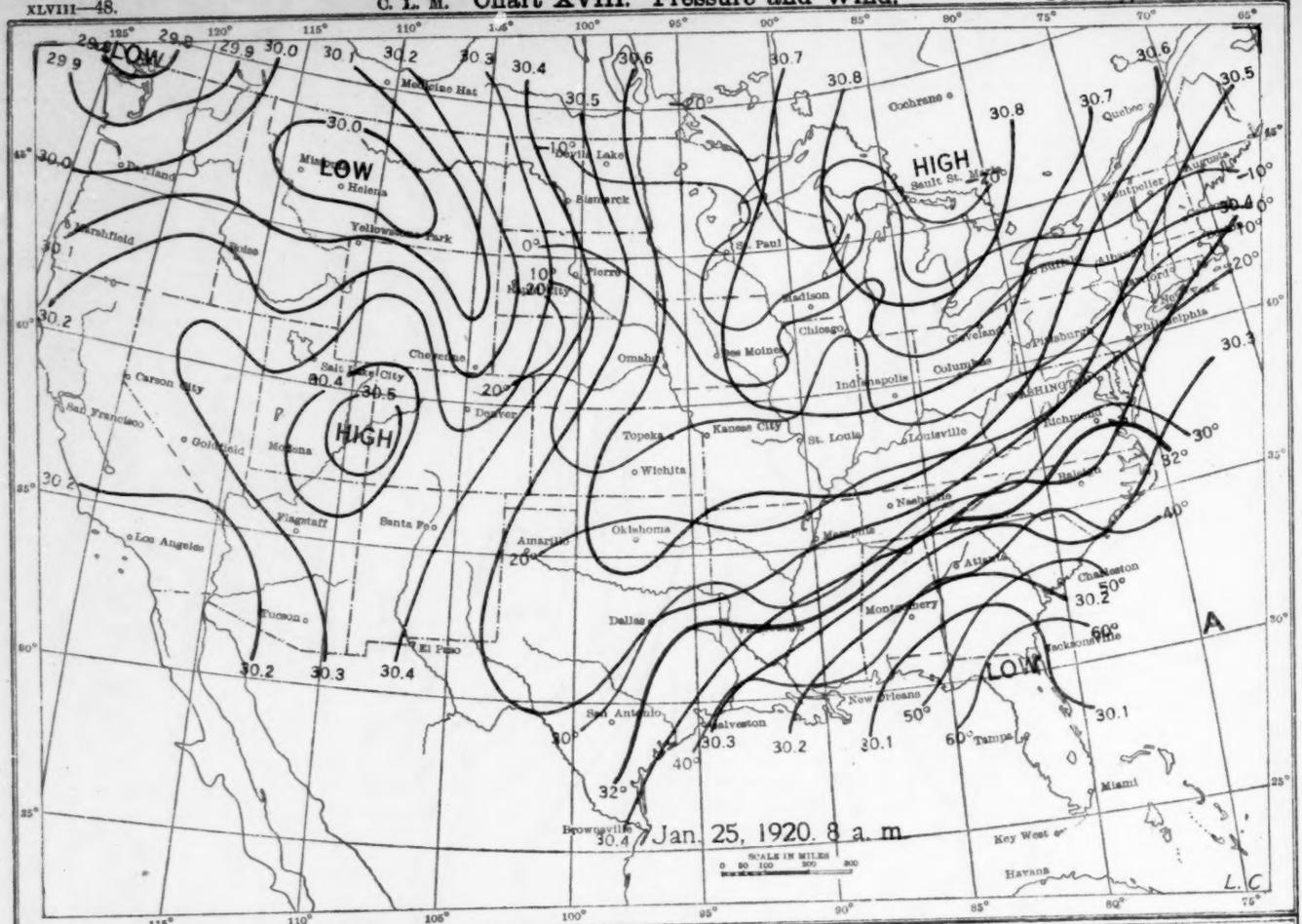

30.2
30.3
30.4
30.5
30.6
30.7
30.8
30.9
31.0
HIGH
30.8
30.7
30.6
30.5
30.4
30.3
30.2
30.1
30.0
LOW
Medicine Hat
Devils Lake
Bismarck
Portland
Missoula
Helena
Marshfield
Yellowstone Park
Boise
Pierre
Rapid City
Cheyenne
Salt Lake City
Carson City
San Francisco
Goldfield
Modena
Denver
Omaha
Des Moines
Chicago
Madison
St. Paul
Cochrane
Quebec
Montpelier
Augusta
Concord
Boston
Buffalo
Albany
Hartford
New York
Philadelphia
Pittsburgh
Cleveland
Columbus
Indianapolis
WASHINGTON
Richmond
Kansas City
St. Louis
Louisville
Topeka
Wichita
Oklahoma
Amarillo
Flagstaff
Santa Fe
Los Angeles
Tucson
El Paso
Dallas
Vicksburg
Memphis
Nashville
Raleigh
Atlanta
Charleston
Montgomery
Jacksonville
San Antonio
Galveston
New Orleans
Tampa
Miami
Key West
Havana
Brownsville
Jan. 24, 1920. 8 a. m.
SCALE IN MILES
A
B
L.C.

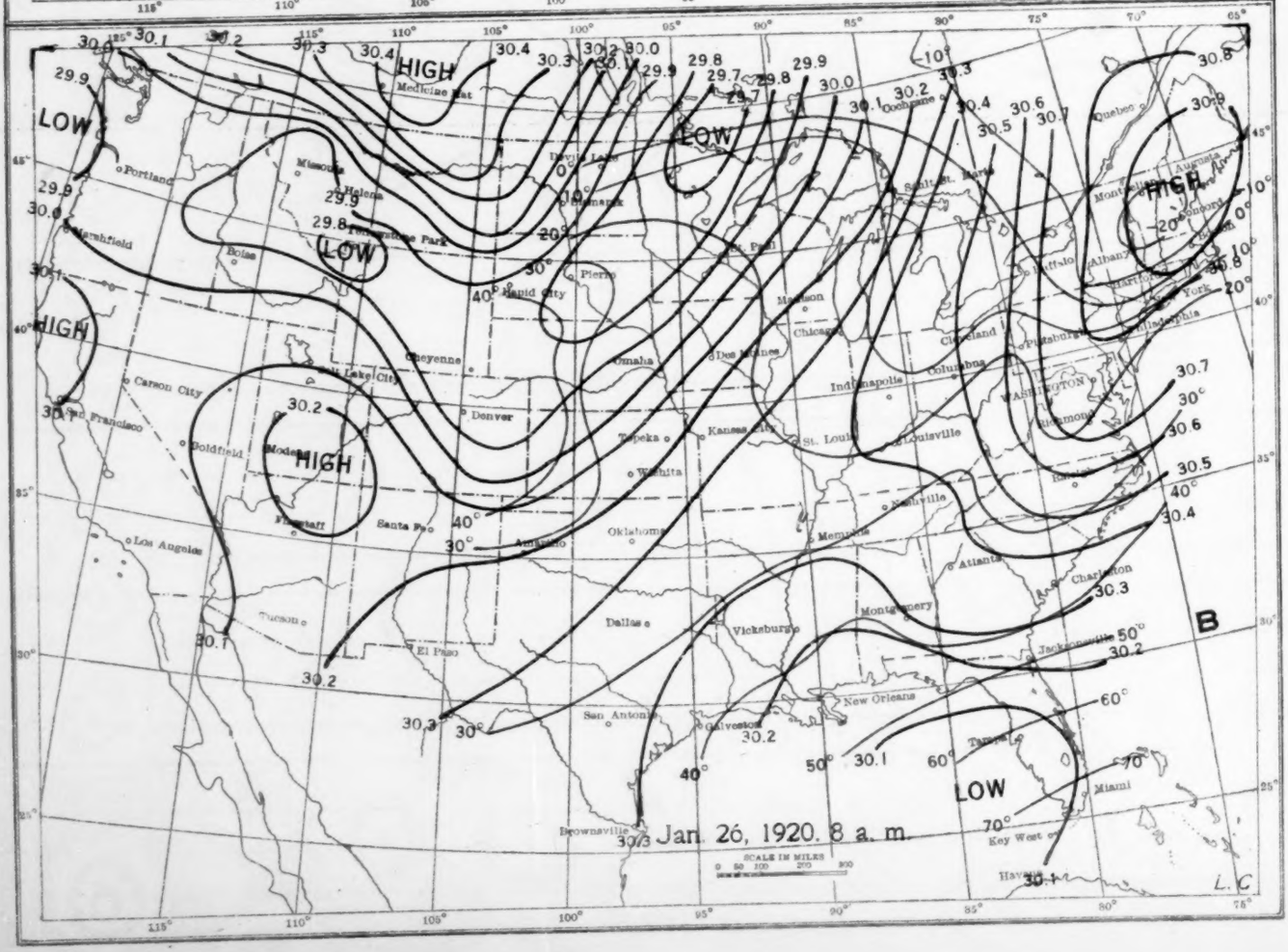

Within preceding 12 hours.
SNOW
SLEET
RAIN
H.B.
A
B
Jan. 24, 1920 8 a. m.
Sections showing conditions in lower three kilometers on meridians indicated.
= Snow
= Sleet
= Rain
Within preceding 12 hours.
= Glaze forming.
= Kite observation.
= Balloon observation.
WIND BOUNDARY
CLOUD BASE
FOG
3 km.
2 km.
1 km.
Surface
A
B
C
D


LOW
HIGH
HIGH
HIGH
LOW
30.9
30.8
30.7
30.6
30.5
30.4
30.3
30.2
30.1
30.0
29.9
Medicine Hat
Portland
Missoula
Helena
Devils Lake
Bismarck
Sault St. Marie
Marshfield
Boise
Yellowstone Park
St. Paul
Pierre
Rapid City
Madison
Buffalo
Albany
Montpelier
Concord
Portland
Hartford
Chicago
Cleveland
Philadelphia
Carson City
Salt Lake City
Cheyenne
Omaha
Des Moines
Pittsburgh
San Francisco
Denver
Indianapolis
Columbus
WASHINGTON
Goldfield
Modena
Topeka
Kansas City
St. Louis
Louisville
Richmond
Wichita
Raleigh
Flagstaff
Santa Fe
Nashville
Los Angeles
Amarillo
Oklahoma
Memphis
Atlanta
Charleston
Tucson
Dallas
Montgomery
El Paso
Vicksburg
Jacksonville
San Antonio
Galveston
New Orleans
Tampa
Miami
Brownsville
Key West
Havana
A
Jan. 24, 1920, 8 p. m.
SCALE IN MILES
W. T.


Medicine Hat
Ochrane
Quebec
Portland
Missoula
Devils Lake
Sault St. Marie
Marshfield
Helena
Bismarck
Yellowstone Park
Boise
St. Paul
Pierre
Rapid City
Madison
Buffalo
Albany
Montpelier
Concord
Portland
Chicago
Cleveland
Philadelphia
Carson City
Salt Lake City
Cheyenne
Omaha
Des Moines
Pittsburgh
San Francisco
Denver
Indianapolis
Columbus
Goldfield
Modena
Topeka
Kansas City
St. Louis
Louisville
Wichita
Raleigh
Flagstaff
Santa Fe
Nashville
Los Angeles
Amarillo
Oklahoma
Memphis
Atlanta
Charleston
Tucson
Dallas
Montgomery
El Paso
Vicksburg
Jacksonville
San Antonio
Galveston
New Orleans
Tampa
Miami
Brownsville
Key West
Havana
B
Jan. 24, 1920, 8 p. m.
SCALE IN MILES
W. T.


Within preceding 12 hours.
SNOW
SLEET
RAIN
Jan. 24, 1920. 8 p. m.
Statute Miles
Kilometers
Sections showing conditions in lower three kilometers on meridians indicated.
Snow
Sleet
Rain
Within preceding 12 hours.
Glaze forming.
Kite observation.
Balloon observation.
WIND BOUNDARY
CLOUD BASE
FOG
3 km.
2 km.
1 km.
Surface
A
B
C
D


LOW
HIGH
LOW
HIGH
LOW
A
Jan. 25, 1920. 8 a. m.
L. C.


LOW
HIGH
HIGH
LOW
LOW
B
Jan. 26, 1920. 8 a. m.
L. C.

stood: it does not show the actual paths of particles of air, but, on the contrary, merely the directions with which the winds were blowing *at the time of observation.* This method has been devised by Bjerknes [1] and has been used by him in his studies in forecasting in Norway and other parts of the world. Our maps also show, wherever possible, the probable path of the wind of southerly component after it has left the ground at the wind-shift line. In these maps the surface winds are shown in red and the probable course of the southerly wind aloft by dotted lines.

Opposite these maps, for a given time, is the map showing the distribution of precipitation of various kinds during the preceding 12 hours. This shows, in overlapping areas, the character of the precipitation. By placing the isotherms on this map we are able to show the region which probably includes the areas over which glaze formed, namely, all that area north of the freezing line (32° F. isotherm) over which rain fell during the preceding 12 hours. In addition to the isotherm of freezing, which, owing to its importance is more prominent than the others, the isotherms of 25°, 20°, 10° (F.) etc., are marked north of the freezing line, and 40°, 50° (F.), etc., are marked south of the freezing line.

On the lower part of the precipitation and temperature map, we have prepared sections of the lower 3 kilometers of the atmosphere along selected meridians. The meridian selected is noted by a heavy black line on the map, and its corresponding section below is found by means of the index letter. These sections are the result of putting together those fragmentary data which, owing to the regrettable scarcity of aerological stations in the United States, consist of isolated temperature measurements at various levels in the free air, and of wind directions and speeds, amplified with speculations which are based upon previous observations. Thus, while these sections can not lay claim to being actual representations of the conditions aloft, they may be regarded with considerable confidence.

These maps have been prepared for every 12 hours throughout the period under investigation, beginning with January 21, 8 a. m. The last two maps (Chart XVIII) show the pressure and temperature conditions on January 25 and 26, to connect the weather of this period with that of the 27th to 31st discussed in the following article in this REVIEW.

GENERAL SURVEY OF THE PERIOD.

Pressure.—The period opens (Chart I, pressure and wind-shift are noted on same map with other data for January 20, 8 p. m.) with the territory under consideration flanked by high pressure in the northwest, northeast, and southeast, with moderate depressions in the Lake region and in the Southwest. The subsequent changes of pressure served to produce a general broad area, or wall, of high pressure along the northern part of the United States, while there was a general decrease toward the Gulf which was manifested in the Gulf States by a fairly persistent protuberance of lower pressure which extended from the Gulf to western North Carolina and Virginia (Chart IVa). The general area of high pressure off the southeast coast was also quite persistent. On the morning of January 23 a small depression was centered over northeastern Arkansas (Chart Xa) and by evening of the same day was elliptical in form with its major axis roughly parallel to the Appalachian Mountains. With the strengthening of the high pressure in the north and the appearance of a center in northern Minnesota on January 24 (Chart XVIa), the isobars assumed a southwest-northeast trend with the protuberance of low pressure, previously mentioned, lying along the south Atlantic coast. This was followed, coincidently with the general disappearance of sleet conditions, by an easterly motion of the HIGH to the Lake region, and the southeastern LOW to Florida (Chart XVIII), on the morning of January 25.

What is the significance of this pressure distribution, with respect to the conditions favorable for sleet and glaze? We mentioned above that one of the major premises of a sleet forecast is the presence in the southeast of a HIGH, the temperatures within which are not so low as usual, just off the coast of southeastern United States. Such a condition persisted until the last few hours of the period. Moreover, the belt of high pressure, evidently centered far north in Canada, gave an abundant supply of cold air, sweeping down from the deep snowfields of the north far into the United States toward the general area of low pressure along the southern coast. The return flow of warm moist air, riding over the wedge-like encroaching north wind, was cooled and forced to precipitate rain, sleet, or snow over most of the eastern United States throughout the period.

Wind.—Now, let us look to the charts of instantaneous stream lines of surface wind. Chart I shows a strongly marked wind-shift line (heavy dotted red line) extending from Texas northeasterly toward the center of low pressure over Lake Erie. South of this line all the winds, with certain exceptions in the mountain district where topography prevents the surface air from flowing readily with the general wind not far aloft, have a south component. (Indicated on Chart I by heavy red arrows.) All winds north of this line have a north component. Chart IIb shows the same wind-shift line extending from east Texas to New England with a slight break in North Carolina, owing to the slight depression centered in that region. Throughout the period, it is possible to see this line, sometimes rather indefinitely located, as in Chart VIb, for instance, but recovering its identity a few hours later as in Chart Xb. As the end of the period approached, the sweep of the northerly wind became greater until finally it covered the Gulf and South Atlantic coasts. (Charts XIVb, XVIb, XVIIIa.)

Temperature and precipitation.—The picture of the current weather is completed, as far as our interests are concerned, by the odd-numbered charts, which show the temperature at the surface and the areas over which various kinds of precipitation have occurred in the preceding 12 hours. Briefly, attention is called to the general aspects of these charts. The period begins with general precipitation west of the 95th meridian. The area of glaze covers Illinois and the northern portions of Indiana and Ohio, and again in the east, a considerable portion of the Middle Atlantic States. Sleet also fell over a large area from Lake Michigan eastward to the Atlantic and as far south as Philadelphia. The following 12-hour period shows the major portion of the sleet area to lie in Missouri and southern Illinois and Indiana (Chart III), with another, smaller area in Pennsylvania and New York. Attention, however, should be called to the fact that the maps representing precipitation during the night hours seem to show a tendency toward spottedness of sleet. It is believed that this is attributable to the lack of close and careful observation during the night hours. Even during

[1] Bjerknes, V. F.: Synoptical representation of atmospheric motions. Quar. Jour. Royal Meteorological Soc. 36: 267–286; also, Weather forecasting, and, On the structure of moving cyclones. MONTHLY WEATHER REVIEW, February, 1919, pp. 90–99.

the day it is an easy matter to fail to note sleet when it is falling in small quantity with rain or snow, and the night would only increase the difficulty. This, combined with the less vigilant night observations, might account for the spottedness of sleet areas. The general trend of the isotherm of freezing throughout the period is from southwest to northeast and the rain areas conform in general to the same direction, the rain belt extending roughly equal distances on either side of the isotherm. As the period draws to a close the areas of sleet and glaze grown smaller and, while large areas of snow and rain are still prevalent, the sleet and glaze producing conditions are disappearing.

Another outstanding feature of the temperature distribution is the distinct northward hook in the mountain region, the line of freezing often proceeding far north of its general trend because of the inversion of temperature which results from the overrunning warm wind from the south. The lower stations, therefore, are in the northerly wind, but those of greater elevation project up into the warmer region and swing the isotherms far from their normal course, i. e., the course they would probably pursue if the mountain region were absent. This inversion is nicely shown on Chart VII in which Elkins, W. Va., shows a temperature several degrees higher than the territory in its immediate neighborhood. Toward the end of the period, with deep northerly winds, the opposite is the case (Chart XV), for Elkins has a temperature considerably lower than that of the surrounding country.

THE MERIDIONAL SECTIONS.

Example.—In order that the significance of the small meridional cross-section maps may be thoroughly understood, the method employed in drawing them will be followed through for one case, which is fairly complete in details. Not all of these sections are of equal weight owing to the lack of upper-air data in many cases, but the reasoning employed in their construction is something as follows: Let us take Section A on Chart III, which represents the conditions along the 83d meridian at 8 a. m., 75th meridian time, January 21. The general nature of the topography is indicated in solid black. The surface temperatures, that is, the points where the various isotherms of the map above intersect the black line AA, are indicated along the "surface" line. From Chart IIb, on the opposite page, we find that the wind-shift line crossed this meridian in northern Georgia, which is to say that all winds south of the line had a southerly component and all winds north of the line had a northerly component. Moreover, that same morning at Leesburg, Ga., a kite flight was made. The conditions there were fog at the surface and winds of southerly component as high as 3 kilometers. The surface temperature was 57° F.; and at 1, 2, and 3 kilometers were 52°, 51°, and 41°, respectively. The record showed a layer of stratus cloud having its base at about 1,200 meters, and its top as indicated by the hygrometer and thermograph, at about 1,500 meters. Within the cloud, the temperature fell to 50°, which is approximately according to the retarded adiabatic rate. Immediately at the top there was a sudden rise to the 54° observed at 1,500 meters. Above that level the temperature fell at the greater rate of about 1° F. per 100 meters.[5]

[5] Unfortunately, it was necessary, owing to the manner in which data are presented by Weather Bureau stations, to employ temperatures and pressures in Fahrenheit degrees and inches, respectively, and altitude in meters. But since the mixing of the systems of units, in this case, does not result in confusion, the author has refrained from the conversion of large numbers of observations to metric units.

At Lansing, Mich., where a pilot balloon run was obtained, winds of northerly component up to 2 kilometers showed clearly that the wind-shift line which was on the ground in northern Georgia must lie somewhere aloft in the intermediate distance. Royal Center, Ind., which is in the vicinity of the meridian in question, showed a northerly component at 1 kilometer and clouds at about 1,500 meters. What clue can that give to the location of the wind-shift line? It is likely that at the boundary between the winds of north and south component, there will be clouds formed by mixture, that is, the mixing of the cold air from the north with the warm, moist air from the south, will produce a region of intermediate temperature, below the dew point for air of that moisture content, with the result that cloud will form. Thus, if we find cloud at 1,500 meters above Royal Center, we are probably not far wrong in saying that that is the boundary between the winds of north and south component; hence, we will be justified in joining the wind shift at the surface with this point in the free air and call that line our "wind boundary," and since fog is not found north of the wind-shift line we may assume that the wind boundary forms the cloud level. The upper level of stratus which we found at Leesburg, Ga., will intersect this wind boundary and will extend as far north as surface stations report cloudiness, which was approximately in central Ohio. From Leesburg north to the point where the wind boundary is encountered, the base of the stratus cloud will probably be lowered, because of the horizontal temperature gradient at the surface which will tend to bring the dew-point level nearer the surface; at the same time, the cloud layer will thicken because the air is rising, in other words, the top is raised by forced ascent as the warm air rides up over the wedge of cold air from the north.

Now, let us consider the vertical distribution of temperature, which may be well surmised, knowing the surface horizontal distribution and the upper-air conditions with respect to height and thickness of clouds, and wind direction. Beginning with the 32° isotherm we find that it lies well within the north wind, thus the likelihood of a temperature inversion is small and if it did exist, it would not be very strong; hence, we can assume the temperature gradient up to the cloud base is the normal for winter. But as soon as the south wind is encountered the temperature at that point is certain to be considerably higher, since the temperature of the south wind when it left the ground was about 52° F., and, judging from the slight cooling due to ascent, and due to latitude it is very certain that the isotherm of freezing must swing decidedly to the north. How far north will it go? We must now look to the areas of different kinds of precipitation, shown on the map above. We find that rain fell from the vicinity of the wind-shift line at the surface in Georgia to central Ohio. About half the rain area, along the 83d meridian, lay north of the surface freezing line. But we know that if rain falls upon earth below the freezing temperature, there must be a higher temperature aloft in which rain may form or in which the snow will melt as it falls through. Such a layer must, obviously, be above freezing. So we carry our freezing line from the point where it enters the cloud closely along the wind boundary to the northern limit of the glaze belt, or, more strictly, the northern limit of rainfall of the preceding 12 hours.

This brings to light the fact that the sections are not synchronous throughout, but that the surface location of the 32° isotherm is current, whereas its northern limit aloft is really its northern extreme during the preceding

12 hours. Sleet is formed by partially (or totally) melted snow falling into a cold layer and refreezing, or by the freezing of raindrops in the air; but since no sleet fell on on this meridian we should be led to think that the thickness of the layer whose temperature was above freezing was large, since no snow, which may have fallen from higher levels, was able to get through only partially melted. Curving the freezing line back at this point, we start it in a southerly direction again at the retarded adiabatic rate. Taking the 40° isotherm, in a similar manner, we raise it at a normal rate to the cloud level, then sharply northward, as it encounters the southerly wind, but not so far as the 32° line. As it rises through the cloud it follows the retarded adiabatic rate until it reaches the cloud top, where there is a sharp inversion (mentioned before in connection with the observed 51° at Leesburg), and then it proceeds at a more rapid rate, say 1° F. per 100 meters.

We have then, the picture of the processes at work in producing glaze formation, the underrunning north wind, the overriding south wind, the immense value of even a few kite and pilot balloon observations, in piecing together a cross section of the phenomena of the upper air. Not all the sections will be so complete. Some are devoid utterly of assistance from the upper-air observations, because there were no stations near enough whose observations could be considered as applicable to the meridian in question. This detailed explanation of the method of constructing a cross-section shows what considerations were given to each of the others, to a greater or less degree.

Some interesting features.—As one follows through the sections there are a number of points which are brought to notice in a very striking manner. Among the first of these is Section C, Chart III, which shows the effect of gentle southerly winds, ascending over a wedge of northerly wind which is apparently descending. This fact is ascertained from the kite observations at Ellendale, N. Dak., in which we find a wind of northerly component at 2 and 3 kilometers, but of southerly component below 1 kilometer. It is obvious from the stream-line map (Chart IIb) that the southerly surface wind at Ellendale can not be related to the southerly wind of the more southerly latitudes. Hence, we must think of the formation as a series of layers of different direction sliding over one another. The wind-shift line or wind boundary probably does not extend far north as we have assumed others to do, but is prevented by the superior strength of the northerly wind. A second wind boundary, unrelated to our investigation, would be that between the southerly and northerly winds above Ellendale.

A similar phenomenon appears in Section C, Chart V, in which the northerly component is introduced by a northeast wind which, at its maximum, is perhaps not over a kilometer and a half in depth. This forces itself like a wedge from the side under the southerly wind, lifting it in a broad hump, but allowing the southerly wind to meet the surface again in the north. This is shown by kite flights at Ellendale, which seem to indicate that an adiabatic temperature gradient prevails above that region. In the south, however, where the isotherm of freezing is to be found, the sky is partly cloudy, marking the northern edge of the cloud level, but the clouds are moving from the south, while just below that level, a pilot balloon observation at Broken Arrow, Okla., discloses a wind of northerly component. Another feature of interest is that the precipitation of the preceding 12 hours occurred all on the windward slope of the wind hump, just as it would on a topographic hump, where a passing moist southerly wind would have been cooled by expansion rising on the southern slope, making precipitation, but warmed by compression flowing down the northern slope, tending to evaporate the clouds.

A warning should be made here. The section we are discussing shows the northern cloud limit considerably south of the northern limit of rain as shown in the symbols beneath, and it is desired to mention again that the precipitation refers to the preceding 12 hours, while the cloudiness, temperature, etc., are current. Confusion in trying to reconcile precipitation with a clear sky will be avoided if this is borne in mind.

Section A, Chart V, shows the northern limit of rain and sleet coinciding with the maximum altitude of the land. This is shown also in Section A, Chart VI; Section A, Chart IX and Section A, Chart XI. There are probably two reasons for this phenomenon, operative in combination. First, as the southerly wind approaches the mountainous regions it is deflected upward by the land itself, causing precipitation from clouds formed by forced ascent; second, it is possible that rain is falling from the cloud all along, but that the surface temperatures in the more southerly region are sufficiently high to evaporate the falling rain before it reaches the surface. But as greater elevations are attained in the topography, and as the surface temperature is lower in more northerly latitudes, rain reaches the surface, chiefly because the earth goes up to meet the rain.

One will notice on Chart XIII, Section B, that there was a narrow region where sleet was reported in combination with snow, and south of the region of sleet and snow there is an area where snow alone fell. It seems natural in the ideal section of the atmosphere that the sequence of precipitation from the south along a given meridian should be rain, rain and sleet, sleet, sleet and snow, snow; and, in general, such a sequence is found. But here we have an area of sleet falling in the midst of a snowstorm. The sky is overcast with low clouds from which snow is falling. Surely there can be no temperature of freezing or above below those clouds and in a northerly wind. We must draw upon our imagination to find the source of the sleet. We know that it may start as snow and fall through a layer of air whose temperature is above freezing, Therefore we may suppose that there is a cloud layer precipitating snow at some elevation above the tongue of southerly air, and that either this cloud area is small because the area of sleet on the ground is small, or that only a small portion of it is under-run by warm air. Hence, we may mark a cloud layer at roughly 2 kilometers. But the presence of this sleet area is made more interesting by an observation made earlier in the day at Leesburg, Ga.

Upon January 23 (Chart XI, Sec. B), after a morning fog had cleared, a layer of [alto]stratus clouds at about 2 kilometers was seen moving rapidly northward. Low clouds prevented us from knowing how far north this layer extended. The wind was of considerable velocity from the south, and if we may assume that the layer extended for a considerable distance north of the place of observation, it is quite conceivable that the clouds which produced the sleet in Section B, Chart XIII, are the same as those headed rapidly northward from Leesburg. This is not a far-fetched conclusion, but is an interesting piece of aerological detective work.

A fourth point worthy of attention is seen in Section B, Chart VII. Here there is no wind-shift line; the surface wind throughout the length of the meridian is northerly. There are no kite stations within the immediate vicinity of this meridian, nevertheless, those at Drexel, Nebr.,

show a wind of southerly component and of temperatures consistent with those at the surface and with the area over which sleet fell. It is therefore probable that over this whole region there was only a shallow north wind and a south wind above it of considerable depth.

Finally, mention should be made of the apparent discontinuity between the areas of rainfall and snowfall. Except for those periods when precipitation was general throughout the eastern half of the United States, as in Chart XIII, there appears a well-defined clear space on the maps in which no precipitation occurred lying between the rain area and the snow area. This shows how the snowfall was probably attributable to a cause quite distinct from that which was producing the rain and sleet farther south. For example, take Charts VII, IX, and XI, in which there is shown the advance from the northwest (first appearing in North Dakota on our charts) of an area of snowfall, first, only a small area being visible, then widening and advancing, and, finally, joining itself to the general precipitation area. The cause of this is probably as follows: A glance at the pressure map VIa shows that a high-pressure area was appearing in this region, and that snow was falling where the pressure gradient was steepest, the precipitation apparently being the result of forced ascent of the air as it flowed into this belt from the rear at a higher velocity than it flowed out in front.

THE STORM OF FEBRUARY 3–6, 1920.

While the precipitation of sleet and the formation of glaze during the period of February 3 to 6 was more local in character and somewhat shorter in duration than the one we have just discussed, it may be safely said that it stands out in the minds of those who experienced it as one of the most severe storms in years. It occurred chiefly east of the Appalachian Mountains, hence, because of the relatively small area covered we have not considered it in the detailed manner of the previous storm, and no charts have been drawn for it. The conditions in New England have had a parallel only in three or four instances. Trains were stalled for days, roofs collapsed from the weight of snow and ice, and in New York City the removal of the snow and ice afforded the most perplexing problem of its kind in the city's history.[6]

The great mass of cold air over the snow-covered north, with its attending area of extremely high pressure, which lay over the North Atlantic States, afforded a strong barrier to the cyclone which, having appeared in the southeastern States, could move but slowly northward, and, therefore, increased markedly in intensity. The circulation about this strong cyclone, in combination with the HIGH in the north, served to send winds of gale force, sweeping from the northeast down the coast for several days. Above this wedge of biting wind there flowed a layer of moisture-laden air from the balmy expanses of the Gulf Stream, and in consequence there was heavy precipitation of snow (several feet) in the interior of New England, New York, and Pennsylvania, with snow, sleet, and glaze-forming rain along the coasts, while farther south there was an unusual quantity and duration of sleet and rain.

On February 3 the cyclone was centered near Savannah. The wind-shift line lay across northern Florida, thus allowing extremely warm air from Florida and the Gulf to ride up over the cold air fed by the strong wall of high pressure in the Lake Region and New England.

[6] See note on "Demoralization of traffic in New York City by snow and sleet," this REVIEW, p. 80.

On February 4, the center of the cyclone had moved out to sea from Savannah, leaving the wind-shift line slightly farther north than on the previous day, but still well marked in southern Georgia and northern Florida.

The cyclone apparently changed its course on February 5 and began to move roughly parallel to the coast in a northeasterly direction. The wind-shift line was no longer in evidence, and the horizontal surface temperature gradient was very slight, although the temperatures were rather low. Precipitation during these days was general along the coast, with heavy snows in the north, which were mixed with rain and sleet. Farther south the sleet and glaze were predominant, the sleet falling in such quantity at Washington, for instance, as to afford a cover several inches deep much like dry sand. Rain, of course, fell in the South Atlantic States. The conditions producing this storm were obviously of the same general nature as those of the previous one, except more intense and more localized. So much warm air blew inland during this storm, that after the storm passed off, the northwest wind was relatively mild in temperature.

PRECEPTS FOR FORECASTING SLEET AND GLAZE.

It was stated in the beginning that the motive for preparing this paper was the desire to find some means to improve the forecasting of sleet and glaze; at the same time it was observed that no one can well anticipate the discovery of a panacea for all the difficulties of this type of forecasting from the study of a single storm. There are, however, certain features of this storm which appear as characteristic, i. e., they seem to persist as long as the sleet and glaze persisted, and, therefore, are probably related. One of these features is the parallelism between the 32° isotherm, the wind-shift line, and the northern limit of rain and sleet precipitation.

While the extreme value of forecasting the location 12 or 24 hours later of the 32° isotherm has been pointed out in a previous reference to the statement of Dr. Frankenfield as to the conditions which produce sleet and "ice storms," it appears that it is also of extreme importance to forecast, and pay quite as great heed, to the location of the wind-shift line. For the two are inseparably related in the production of this troublesome type of precipitation.

The forecaster's desire is to forecast the area over which glaze will form, and the area over which sleet will fall. Heretofore, the centers of these regions have been forecast with fair accuracy, but often the forecasting of the limits has been difficult, if not impossible. It behooves us, then, before this paper can be completed, to investigate the question of whether or not there is any relation between the distance from the 32° isotherm to the wind-shift line, and the values in question, namely, the width of the glaze belt, the width of the sleet belt, and the distance of the center of the sleet belt north of the 32° isotherm. Consequently, these distances have been measured throughout the period along various meridians, and ratios have been formed which may serve as factors in predicting the desired values. The measures were made on 34 meridians during the storm, with no attempt to select specific conditions. In spite of the fact that the expected large divergences from the average do occur, it is surprising, nevertheless, that there is as good agreement as is found. The values which have been determined are presented with the full recognition that their determination has been purely empirical, and with the warning that they should be considered in the same cautious manner in which they are given, since they have been determined from this single storm, and

may be found, when compared with other storms, to show a wide divergence.

We do not ignore the physical basis upon which such relations, as we seem to find by purely empirical measurement, may rest. The distance between the 32° isotherm and the wind-shift line is taken as the basis, and the forecasting of the location of each of these is dependent upon the pressure distribution. But the 32° isotherm is usually found in this type of storm to lie north of the wind-shift line; that is, within the area over which wind of northerly component is flowing, and warming as it reaches the southerly latitudes. The wind-shift line marks the place where the southerly wind leaves the surface and moves northward aloft. Kites and pilot balloons will show how far north this wind has progressed, providing there are enough such observations. The amount of precipitation will depend upon the moisture content of the southerly air. The ultimate extent of the southerly wind aloft will depend upon its speed, and, similarly, the ultimate extent of the northerly wind at the surface will depend upon its speed and the nature of the surface over which it is flowing. These are general considerations which the forecaster is accustomed to make, and which he can make with increasingly great certainty as he is armed with more and more data and observations from kites, pilot balloons, and clouds.

Bearing these things in mind, the empirical values referred to above are now presented, with a rough measure of the certainty or accuracy of the occurrence of the phenomenon:

$$(1)\quad \frac{\text{Width of the glaze belt.}}{\text{Distance between 32° isotherm and wind-shift line.}} = 1.0$$

$$(2)\quad \frac{\text{Width of the sleet belt.}}{\text{Distance between 32° isotherm and wind-shift line.}} = 0.7$$

$$(3)\quad \frac{\text{Distance between 32° isotherm and center of sleet.}}{\text{Distance between 32° isotherm and wind-shift line.}} = 0.8$$

The natural question is, With what accuracy do we know these values? It is obvious that in a proposition of this nature, with only 34 determinations, it is unwise to attempt to apply any statistical formulae for the expression of the probable accuracy. But of the measurements made from the maps, we may make the following statement:

For (1) with 34 cases:
- 11 agreed within 20 per cent of the mean.
- 22 agreed within 40 per cent of the mean.
- 29 agreed within 60 per cent of the mean.

For (2) with 28 cases:
- 8 agreed within 20 per cent of the mean.
- 15 agreed within 40 per cent of the mean.
- 25 agreed within 60 per cent of the mean.

For (3) with 28 cases:
- 7 agreed within 20 per cent of the mean.
- 12 agreed within 40 per cent of the mean.
- 18 agreed within 60 per cent of the mean.

One can judge that the accuracy is only sufficient to warrant interest, and possibly to stimulate investigation into other storms of this type to discover if some such empirical rule can be laid down; for if it can, it certainly will be of value in forecasting.

Let us consider the relation (if any exists) between the distance between the wind-shift line and the 32° isotherm, and (1) the width of the glaze belt 4° of longitude east 12 hours later, and (2) the width of the glaze belt 8° of longitude east 24 hours later. Since the pressure formations, and hence the weather in general, move eastward at a rate which is about 8° per 24 hours, such a relation would be of value, for, knowing the current distance between the wind shift line and the 32° isotherm, it might be possible to predict the area over which glaze will form 4° and 8° farther east 12 and 24 hours later, respectively.

Such measurements were made from the maps with the following result:

$$(4)\quad \frac{\text{Width of glaze belt 4° east 12 hours later.}}{\text{Current distance between wind-shift line and 32° isotherm.}} = 0.9$$

$$(5)\quad \frac{\text{Width of glaze belt 8° east 24 hours later.}}{\text{Current distance between wind-shift line and 32° isotherm.}} = 0.8$$

Stating the accuracy in the same manner as in the previous case we have:

For (4) with 29 cases:
- 12 agreed within 20 per cent of the mean.
- 26 agreed within 40 per cent of the mean.

For (5) with 27 cases:
- 13 agreed within 20 per cent of the mean.
- 17 agreed within 40 per cent of the mean.
- 23 agreed within 60 per cent of the mean.

The accuracy of the first in this determination is the greatest of the whole set, and, if given any relative weight, would be considered the most valuable of the five relations presented in the paper. The second is not so reliable, as might be expected, and ranks about equal with those of the preceding set.

CONCLUSION.

The need for more aerological data.—The conclusion of an investigation of this type leaves much to be desired, for the search for threads among the multiplicity of atmospheric phenomena, which, if traced, may lead to other conclusions of value, is indeed an alluring but endless effort. If fifty or a hundred such storms could be followed through, each supported by adequate observations in the upper air, there is little doubt that much could be learned which the forecasters could use with success. But each storm is a problem in itself which entails weeks of laborious tabulation and study, and, also, only those which have occurred within the last five years have even a few data from the upper air. One of the facts which this paper has brought out, however, is that *we do not have enough observations of the upper air by kites.* There are six kite stations maintained by the Weather Bureau in the eastern half of the United States. There should be at least as many more. If we were only permitted to know the depth of the under-running north wind, the vertical temperature gradient, the moisture content and strength of the southerly wind, and know them for a large number of points throughout the eastern half of the country, the forecasting of sleet and glaze—now one of the most uncertain and difficult—would be rendered relatively easy. It is needless to point out the economy of such a venture, when it is common knowledge that millions of dollars are lost or wasted through lack of preparation for these destructive emergencies. And without the upper air data, the forecasting must rest upon an unstable empirical basis.

The necessity for careful cloud observations.—The value of careful cloud observations can not be overemphasized; carelessly made observations of the kind, amount, and direction of clouds are worse than none at all, yet the average observer is likely to be less careful in this than in any part of his work. Detailed cloud observations can tell a great deal when observations by kites and pilot balloons are wanting; but where the latter are available the clouds form useful and necessary supplementary data.

The wind-shift line.—It seems worth while to mention again the importance of the wind-shift line as a factor in forecasting. Bjerknes has found it of extreme importance in forecasting precipitation; Clayton,[7] also, along similar lines, shows the importance of lines of convergence of winds as factors in forecasting precipitation, and this paper shows with clearness that the wind-shift line plays no small part in the production of sleet and glaze.

ACKNOWLEDGMENTS.

To Dr. C. F. Brooks, who not only suggested the investigation and outlined the methods, but also was willing at all times to give advice and valuable suggestions; to Mr. Willis R. Gregg, who kindly placed all the available aerological data at my disposal and made helpful suggestions; to Mr. Herbert Lyman, who assisted in the laborious tabulation of data from the original records, which form the basis for the accompanying charts; and to others, who, from time to time, displayed an encouraging interest in the study, I most gratefully acknowledge my indebtedness and express my thanks.

DEMORALIZATION OF TRAFFIC IN NEW YORK CITY BY SNOW AND SLEET.

The meteorological record of February, 1920, at New York, will long be remembered by reason of the remarkable storm—heavy precipitation which began to fall in the early morning of the 4th instant, and kept it up until the early morning of the 7th. During that period of about 75 hours, 4.45 inches of precipitation occurred. Of this amount 0.37 inch was rain; 2.11 inches of melted sleet; and 1.97 inches of melted snow. The maximum depth of snow and sleet was 17.5 inches, of which 8.8 inches were sleet and 8.7 inches [were] snow.

This is the record of the storm, as noted in Form 1001 of the New York Weather Bureau station, which caused a tie-up of traffic in the city never paralleled in spite of more excessive snowfall on two other occasions. The *Scientific American* of February 28, 1920, pages 219, 232, and 233, gives an account of the methods used to rid the streets of the immense banks of snow or of their foot-deep slushy content. Trucks were hardly able to get about with facility, traffic ways, only wide enough for a single stream of vehicles, were dug, but this resulted in great tie-ups due to efforts to pass; flame throwers, a remnant of the war, were tried, as well as another heat device, but these were so local in their results that they were impractical; the steam shovel was tried, with fair success, where the drifts were deep enough; a newly constructed snow digger was tried with great success but it was impossible to get enough of this type of machine to be of use in the emergency; finally, the fire hose was used with the greatest effect. This experience should warn all large cities where such storms are a possibility, and lead to the provision of adequate equipment for such an emergency.—*C. L. M.*

[7] Note in this REVIEW, p. 83.

TREMENDOUS SNOWSTORM IN PALESTINE, FEBRUARY 9-11, 1920.

By OTIS A. GLAZEBROOK, American Consul.

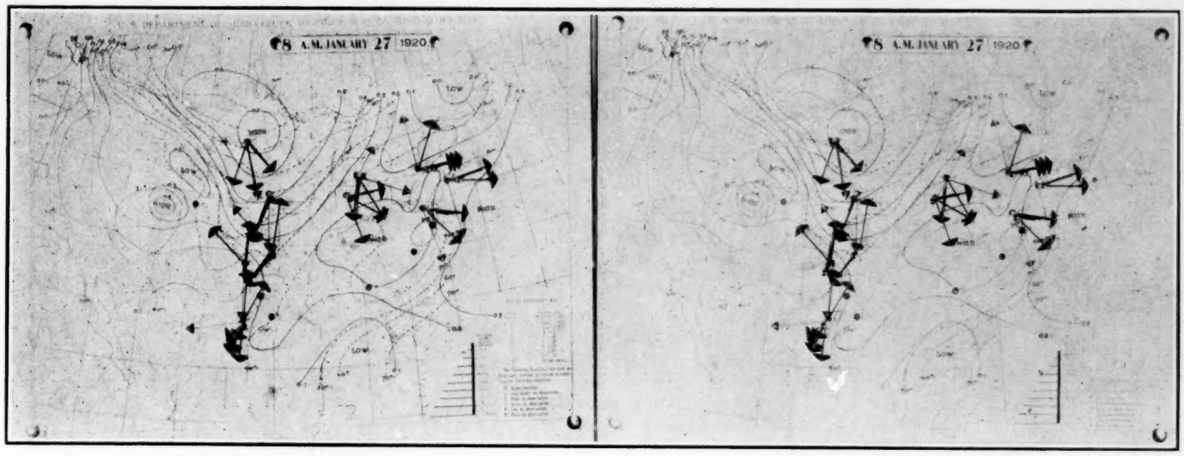
[Jerusalem, Palestine, Feb. 23, 1920.]

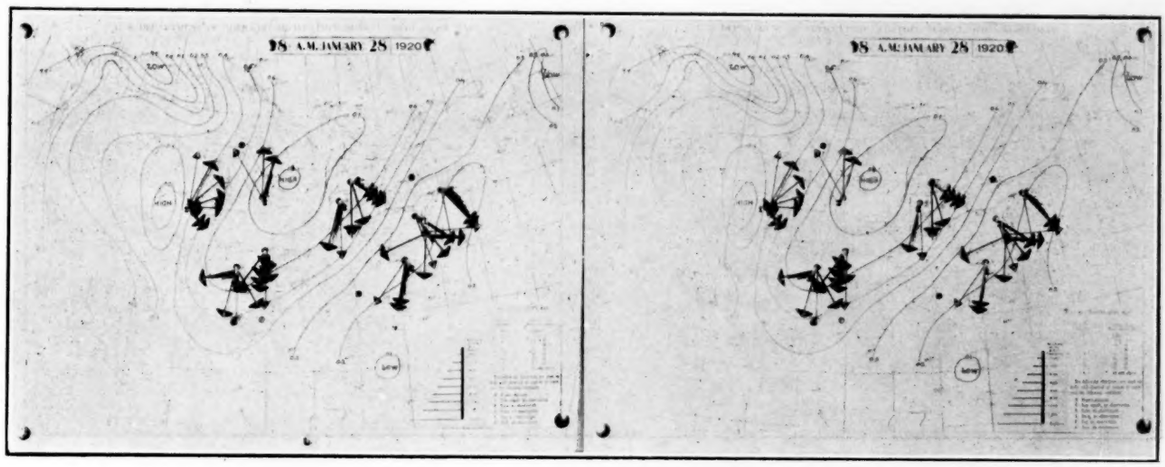
On the afternoon of February 9 a maid of the consulate ran into the house gleefully showing a handful of snow which she had pressed into a snowball. It was the first snow she had ever seen. As the weather had been constantly inclement since the middle of November, 1919, I supposed that this was but a snow flurry ending the former rains, as over 27 inches of rain had already fallen, this quantity being far above the average at this time of the year. In 36 hours afterwards, however, Jerusalem and the surrounding country for miles had been mantled by a snowfall which averaged on the level 40 inches, with drifts in many places reaching a height of 10 feet.

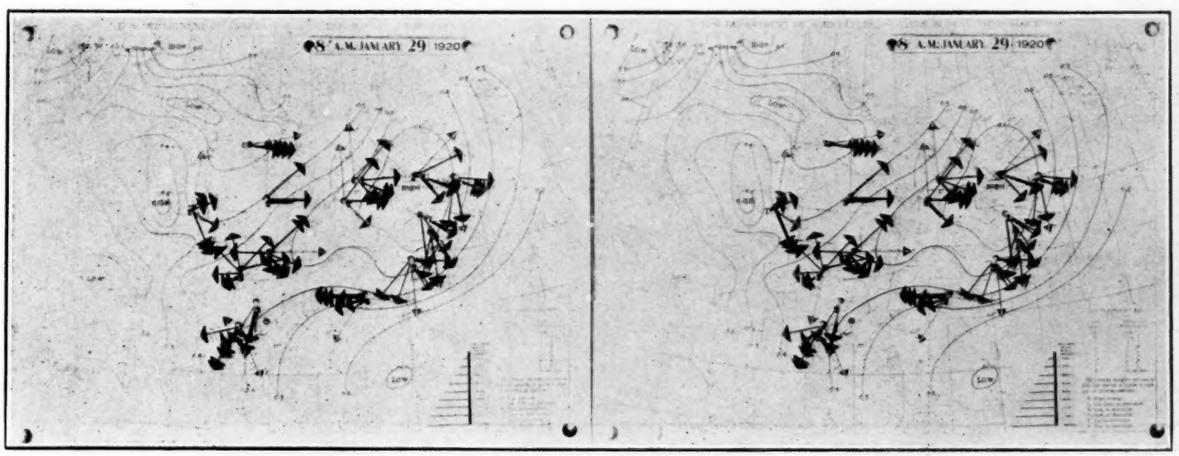
In the memory of the inhabitants of Jerusalem this was the greatest snowfall and the people were absolutely appalled by it. I recall the great blizzard of 1888 and remember many other heavy falls of snow in the United States, but none compared in possibilities of danger to this one. The locust visitation of 1915 falls into insignificance as compared with it. The people of this country being unused to such a phenomenon were totally unprepared to contend with it. There were no snow plows or even snow shovels, and if there had been the population would not have known how to handle them. All communication within the snow limit was interrupted, and the falling of the telegraph wires, the blocking of the railroad and all thoroughfares cut us off entirely from the outside world. Every store was closed. The Felahin could not bring their products to the markets. There was a shortage of bread and a dearth of wood and kerosene, and starvation and freezing faced the people. Fortunately, there is a battalion of Yorkshire troops garrisoning the city. This battalion saved the situation. At once over 700 men were at work with shovels opening the roads and streets in the city and digging out the buried population. When the stores were opened the spirit of profiteering which was already remorselessly abroad in this community—causing the prices of all necessaries, not to speak of luxuries, to increase from five to ten times their former value, having made Jerusalem in the past year possibly the most expensive place in the world, the cost of living being twice as high as in Egypt and in Syria—knew no restraint. In consequence, mob violence was imminent and the military governor was compelled to strenuously reduce the price of bread and other food commodities.

At least 40 houses in Jerusalem were crushed in by the weight of the snow, but, strange to say, the casualty list is comparatively short. When at last unfettered, the inhabitants in general proved equal to the occasion by sharing their own provisions with the poor and improvident. Conditions are now normal, the telegraph and railroad lines being in operation, stores opened, and native products coming into the market. The snow has rapidly disappeared, and except for the continued high winds and unusually cold weather one would not believe that the city had just raised itself from the dead. This blizzard will go down to history as one of the most remarkable and dangerous occurrences in the history of the Holy City, a city by no means unacquainted with extraordinary incidents.

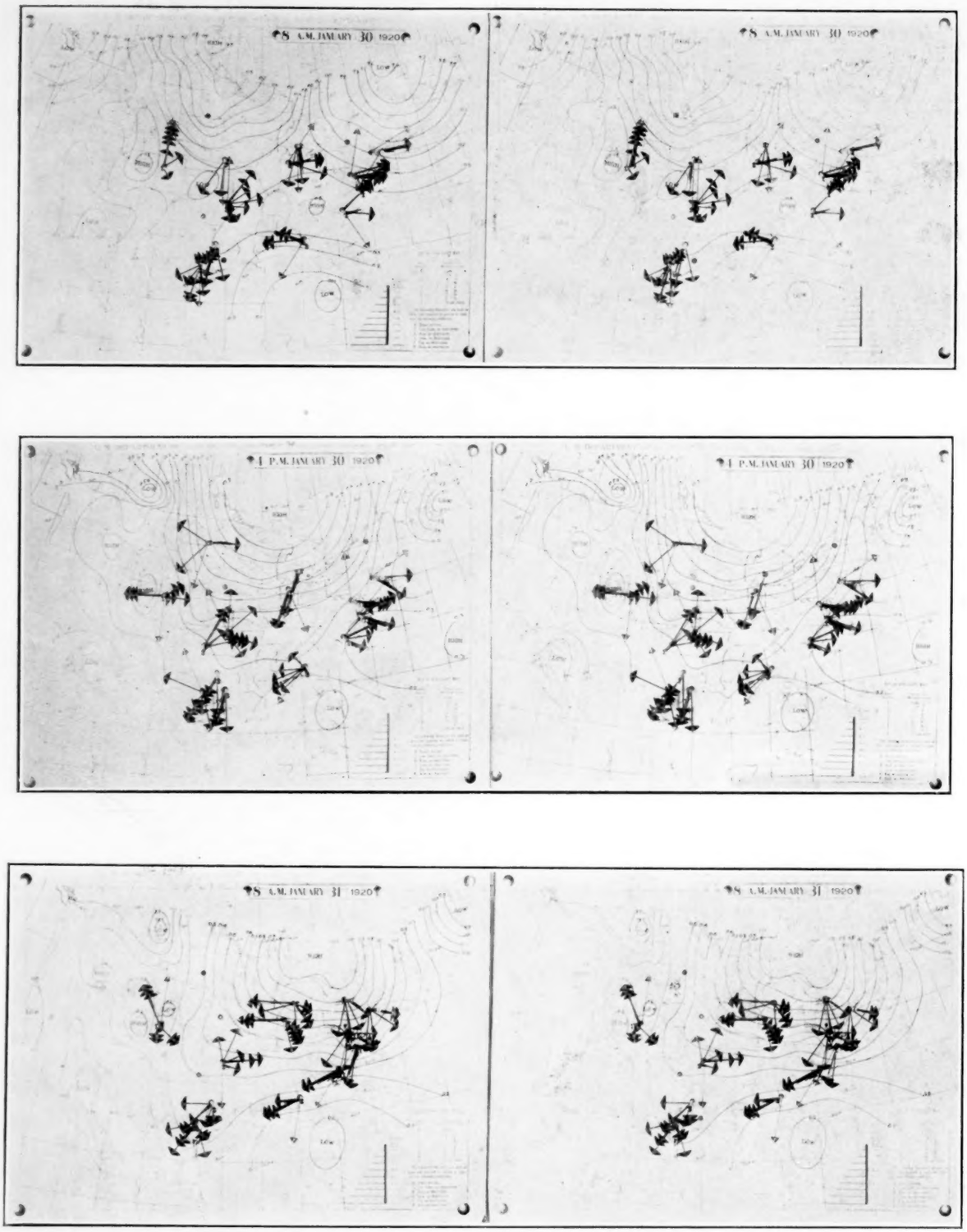
[To face p. 81.]







FIGS. 1–3.—Stereoscopic views of aerological weather maps of the United States, Jan. 27; 28, and 29, 1920.



FIGS. 4–6.—Stereoscopic views of aerological weather maps of the United States, Jan. 30 and 31, 1920. Note the wind changes attending the arrival of a severe cold wave in the northeastern United States the night of Jan. 30.

NOTE ON DEEP NORTHEAST-COMPONENT WINDS OBSERVED JANUARY 27–31, 1920.

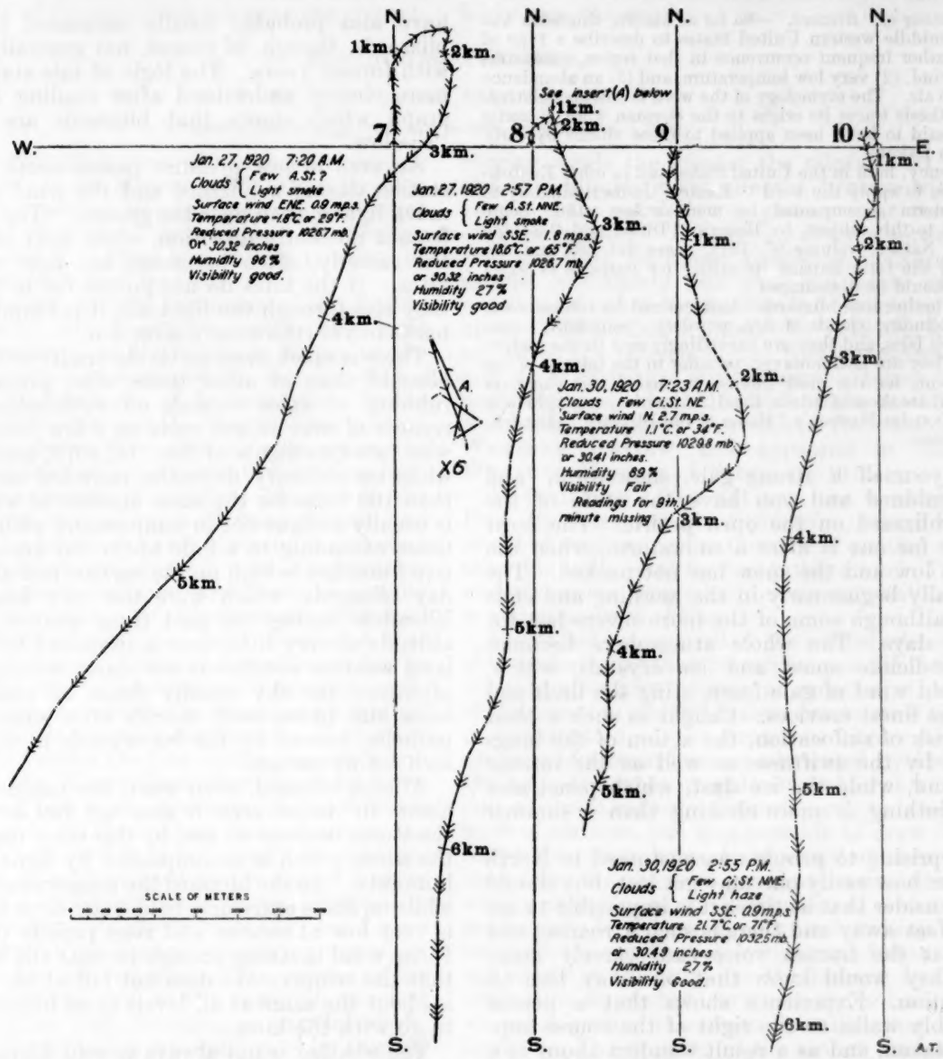
By SAMUEL GOTTLICH, Observer.

[Weather Bureau, Washington, Mar. 29, 1920.]

During the period January 27–31, 1920, the winds at the aerological stations far south, particularly those in Texas, had a northeast component persisting to considerable altitudes. An examination of the weather maps for those days indicates that from Texas some distance north-northwestward there was little temperature change. In fact, on the 29th–31st there were increasing temperatures as northerly latitudes were reached. These warm areas in Wyoming and Nebraska were probably chinook effects. Meanwhile temperatures in Texas were below normal. The result was a spreading apart of the isobars, in the vertical, over the regions north of Texas and a crowding together over Texas; consequently a pressure gradient in the upper strata from north-northwest to south-southeast and therefore northeasterly winds.

The maximum altitude at which these northeast component winds were observed was 10.2 kilometers. Above this level there was a gradual backing to the southwest and then veering back to north at 12.5 kilometers.

The accompanying stereoscopic views (figs. 4–10.) show the surface pressure and temperature distribution over the country and the free-air conditions at selected pilot-balloon stations during this period. Figures 7–10 represent the horizontal projections of balloons at Kelly Field, Tex., on selected days.



FIGS. 7–10.—Horizontal projections of pilot balloon flights from Kelly Field, Tex. The barbs for each minute indicate wind velocities in beaufort numbers. The directions and speeds indicated at the ends of the projections for figs. 7, 8, and 10 are the means for the remainders of the flights, which continued for several minutes more.

In connection with the ascension at Kelly Field on January 27, 8 a. m., the following meteorological phenomenon was observed:

At the beginning of the observation, what appeared to be a combination of fog and smoke was observed banked to the east and northeast of the station. No outline of the city of San Antonio could be seen,

although the visibility in every other direction was good. At 7:30 a. m. smoke sheets in pronounced billow formation began moving toward the station with good velocities. This phenomenon was unusual on account of the great amplitude and wave lengths of the billows, which passed only a short distance overhead, but a little frayed and torn, suggesting the appearance of a large blanket being whipped by the wind. As indicated by the wind-aloft-data from this observation there appeared a stratification of air currents near the surface which probably accounted for the billow formation. Further in this connection attention is invited to the great difference in temperature observed in San Antonio, where there was the protective covering of fog and smoke, and at Kelly Field, 5 miles to the southwest, where free radiation was possible. The temperature in San Antonio at 7 a. m. was 40° F., while at Kelly Field it was 29° F

Attention is called to the surface and free-air wind conditions attending the cold wave that overspread the northeastern part of the country on January 31.

BLIZZARDS AND CHINOOKS OF THE NORTH DAKOTA PLAINS.

By F. J. BAVENDICK, Observer.

[Aerological Station, Ellendale, N. Dak., Mar. 16, 1920.]

Note on the meaning of "Blizzard."—So far as known, this term was first used in the middle western United States to describe a type of winter storm of rather frequent occurrence in that region, characterized by (1) high wind, (2) very low temperature, and (3) an abundance of fine snow in the air. The etymology of the word is still speculative. A plausible hypothesis traces its origin to the German word *blitzartig* ("lightninglike), said to have been applied to these storms by early German settlers in Dakota.

There is a tendency, both in the United States and in other English-speaking countries, to apply the word "blizzard" indiscriminately to any heavy snowstorm accompanied by more or less wind. Some remarks pertinent to this subject, by Bostwick, Dines, and Bonacina will be found in Nature, volume 97, 1916, pages 261, 280, and 301. This broad use of the term impairs its utility for purposes of exact description, and should be discouraged.

It is doubtful whether true blizzards, characterized by intense cold, high wind, and blinding clouds of dry, powdery "snowdrift," ever occur in the British Isles, and they are exceedingly rare in the eastern United States. They are not, however, peculiar to the interior of the American Continent, for the most intense storms of this character heretofore recorded are those of Adelie Land, Antarctica, so graphically described in Sir Douglas Mawson's "Home of the Blizzard" (London, 1915).—*C. F. Talman.*

Picture to yourself a strong gale, snowstorm, and cold wave combined and you have the state of the weather in a blizzard on the open prairie. The most favorable time for one is after a snowstorm, when the temperature is low and the snow has not packed. The blizzard generally begins early in the morning and ends about sunset, although some of the more severe last for three or four days. The whole atmosphere becomes filled with needlelike snow and ice crystals, which, driven by a cold wind of gale force, sting the flesh and sift through the finest crevices. Caught in such a blast one runs the risk of suffocation, the action of the lungs being stopped by the swiftness as well as the intense cold of the wind, while the ice dust, which penetrates the thickest clothing, is more choking than a summer dust storm.

It seems surprising to people unaccustomed to North Dakota weather how easily one may get lost, but should they stop to consider that at times it is impossible to see more than 10 feet away and there is such a roaring and commotion that the human voice can scarcely make itself heard, they would know that one may lose all sense of direction. Experience shows that a person almost invariably walks to the right of the course supposedly being taken, and as a result wanders about in a circle. As a safeguard against this danger some farmers stretch wires from their houses to outbuildings.

Some cattle roam at will and thrive on the grasses without any care or shelter; but during a blizzard they wander aimlessly here and there, sometimes being buried under drifted snow or, in vain attempts to find food and shelter, more frequently traveling with the wind, for no animal will face the storm.

The storm is much more severe on the open prairie than in town because the buildings offer resistance to the wind. The buildings, trees, and cultivation of the soil have also probably locally decreased the severity of blizzards, though, of course, not generally, as compared with former years. The logic of this statement may be more clearly understood after reading the next paragraph which shows that blizzards are comparatively "shallow."

An area of low pressure passes south or east of the station during a blizzard and the wind aloft is usually much lighter than near the ground. The surface wind is from a northerly direction, while aloft it veers toward the easterly, often becoming too light to support the kites. If the kites do not go too far to the west and if they rise through the light air, it is found that the wind backs to a northwesterly direction.

There is much more static electricity in the air during a blizzard than at other times, due, presumably, to the rubbing of snow crystals on each other. There are records of over 10,000 volts on a few hundred meters of wire (see kite flights of Nov. 10, 1919, and Mar. 3, 1920), while on ordinary days the recorded amounts are less than 100 volts for the same amount of wire out. There is usually a slight rise in temperature with altitude sometimes extending to a mile above the surface. The relative humidity is high on the surface and aloft. The one-day blizzards, which were the only kind observed at Ellendale during the past three winters, extend to an altitude of very little over a thousand feet. Above this level weather conditions are about normal. Late in the afternoon the sky usually clears off entirely, while the snow still blows until shortly after sunset. Halos and parhelia, caused by the ice crystals in the air, are often seen before sunset.

After a blizzard, even when the temperature drops to about 40° below zero, it does not feel so cold as during the storm because we are, by this time, near the center of the HIGH, which is accompanied by light wind and low humidity. In the blizzard the temperature drops all day, while on these extremely cold, calm days the temperature is very low at sunrise and rises rapidly during the day. If the wind is strong enough to raise the kites it is found that the temperature does not fall at the usual rate but is about the same at all levels to as high as it is possible to go with the kites.

The weather is not always so cold during the winter or it would be impossible to raise live stock. Sometimes the temperature changes almost 100° F. in a few days, as on February 21 to 23, 1918. This is caused mainly by the effect of the chinook winds. The approach of the chinook is marked by a falling barometer, the winds are light, the sky is cloudless, and the air clear and cold. Objects stand out in bold relief against an intensely blue sky. On some mornings it is possible to see objects which in reality are below the horizon. This is a condition known as looming. The surface wind is always light and generally from the south while, when it is

possible to get up with the kites, it is found that the wind is strong and from the west less than a thousand feet above the ground. There is always a big inversion of temperature often amounting to about 30° F. about 500 feet up. This warm air floating above the cold, almost calm surface air causes the inverted image to appear above objects near the horizon. This effect is related to the chinook from the Rockies. The high temperature aloft may come down, but more often there is a big temperature inversion for a few days and then the warm stratum of air disappears.

Sometimes during such pressure distribution, i. e., a HIGH near Utah and a LOW north of Montana or the Dakotas, the effect of the chinook is felt near the ground. The wind is from the southwest to northwest on the surface and aloft it is directly west. Instead of being strong on the surface and light aloft, as in the blizzard, it is light on the surface and very strong aloft. The temperature at this time is much higher above the ground than at the surface and continues so during the entire period of the warm wave, as shown by kite flights in series of November 17 and December 3–4, 1919. The surface wind increases in strength and warmth during the day, but the wind is not so dry and warm as when it crosses the regions nearer the mountain slope, because it has been absorbing moisture and losing heat for a great distance. Nevertheless it is still very warm and dry and fairly eats the snow.

WEATHER FORECASTING.

By H. H. CLAYTON, Chief Forecaster.

[Argentine Meteorological Office, Buenos Aires, Argentina, Feb. 3, 1920.]

The very interesting discussion of weather forecasting by Prof. V. Bjerknes in the MONTHLY WEATHER REVIEW of February, 1919, leads me to recount how a somewhat crude conception of his methods arose in the United States Weather Service, and to suggest how certain relations of the wind to the gradient may be utilized.

In 1892, when acting as local forecaster of the Boston section, I was called into Washington with other local forecasters for the study of the methods in use in the Central Office. There I encountered Mr. Bassler, of Cincinnati, and Mr. Wappenhans, of Indianapolis. In the course of our various discussions Mr. Wappenhans pointed out his use of a line drawn through a low area separating the winds having a northerly component from those having a southerly component of motion. He said it was useful in predicting rain, changes of temperature, and changes of wind. I began drawing these lines and soon convinced myself of their usefulness in predicting weather changes a short time in advance and hence especially useful to a local forecaster. Mr. Wappenhans offered no reason for the observed relations, but I concluded that the rains observed along the line indicated were due to the underrunning of the warm southerly by the cold northerly winds, whereby the southerly winds were chilled by expansion and their moisture condensed. If this was so, I reasoned that besides the line running nearly north and south, which Mr. Wappenhans drew, there might be another nearly east and west separating the cold winds on the northeast side of the cyclone from those on the southeast side. These two lines run nearly at right angles to each other, as is illustrated by the dotted lines in figure 1. In making local forecasts at Boston I frequently drew these lines, either actually or mentally, and I soon found that they were both lines of converging winds. I came to consider the convergence of the winds as the main factor to be considered as the cause of rain and associated fair weather with diverging or parallel winds. It seemed to me that this view was confirmed by tropical cyclones around which there were no great difference in temperature, yet the converging winds produced ample rainfall.

Later, as meteorologist of the Blue Hill Observatory, I became associated with Mr. John P. Fox, who volunteered to assist in certain lines of research. Among those we took up the question of converging winds. The evidence showed clearly that rainfall was intimately associated with converging winds, and Mr. Fox discovered that the quantity of rainfall was related to the steepness of the gradient. In other words, the more rapid the converging winds the greater the rainfall. It was evident also that humidity was a factor, because with equal convergence the rainfall was greater near the coast than over the interior. This work was done between the years 1898 and 1903, but never published, because it was considered incomplete and was laid aside owing to the pressure of other work with the intention of taking it up and completing it later. In 1912 the idea was presented to the officials of the Weather Bureau at Boston and at Washington with examples taken from current weather maps. In 1916, with slight modifications, the essay thus prepared was offered for publication in the WEATHER REVIEW and appeared in the MONTHLY WEATHER REVIEW of February, 1916.

At that time I had not seen the masterly studies of Prof. Bjerknes and Mr. Sandström, who deserve all the credit of originating the theory and putting it on a sound scientific basis; also for first publication. That the facts underlying the theory had been partly outlined by others is a testimony to the truth.

I have not yet seen all of the published results of these able workers, but their researches printed in the MONTHLY WEATHER REVIEW contain no mention of certain phases of the question which I believe can be used by forecasters in anticipation of the numerous observations and the drawing of stream lines as advocated by Prof. Bjerknes. Owing to the great irregularities of local winds it is difficult to draw correct stream lines from a scattered network of stations, but it is possible to draw fairly correct barometric lines, hence I am accustomed to draw stream lines from the observed gradients, using observed winds simply as guides to the inclination of stream lines to the gradients. In the average for land stations in temperate latitudes the wind has an inclination of about 45°. Drawing winds at this angle to the isobars, but making the inclination somewhat less where the isobars are crowded, we get a system of stream lines like that developed in figure 1. The drawing of the stream lines as applied to an actual case in the Northern Hemisphere is shown in figure 2. (See dotted lines.)

Where there are no well-developed HIGHS and LOWS, but the isobars have a wavy form, as illustrated in figure 3, the relations may be embodied in the general statement that isobars concave to the gradient induce converging winds resulting in ascending currents, cloudiness, and rain, while convex isobars induce divergent currents with descent of air and fine weather.

In figure 3, *L* indicates the direction in which the pressure is low and *H* the direction of high. *L'* shows the

V-shaped depression described by Abercrombie in which the convergence is large and the opposing winds give rise to active condensation. Drift is also a factor tending

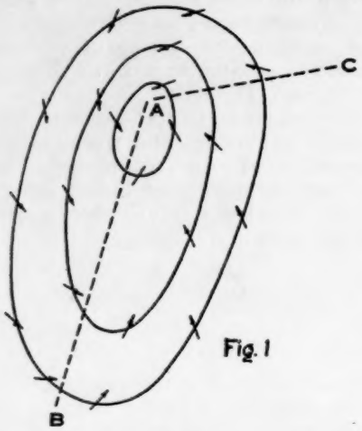


Fig. 1

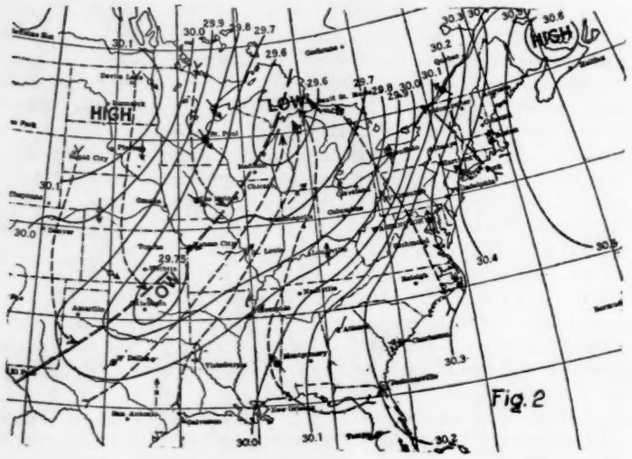


Fig. 2

NOTE.—Figure 2 is from weather map of Jan. 23, 1913. (Broken line shows division between northerly and southerly winds, dotted lines out the directions of flow.)

to modify the component of ascent, increasing it on the side toward which the LOW is drifting and diminishing on the opposite side. Differences in density also play a part, all of which will no doubt be computed and allowed for in the completed scheme of Prof. Bjerknes.

My method of applying these principles to forecasting is as follows: By means of the pressure changes for 12 and 24 hours and their direction of drift I anticipate the changes to be expected during the next 12 or 24 hours. These predicted changes are then added to the pressure distribution of to-day in order to anticipate the pressure distribution of to-morrow.

On the map showing this pressure distribution a system of stream lines is projected in the manner described above.

Another phase of this question of rain areas is one of great interest and possible practical application for precise forecasts made for short intervals in advance. In our investigations Mr. Fox and I found that the rain areas usually could be followed from place to place as easily as areas of low pressure or other meteorological phenomena.

By means of the reports of the volunteer observers of New England we traced the progress of rainfall areas

Fig. 3

across New England for several years and reached the conclusion that, if telephonic reports of the beginning of rain could be obtained from western and southern New England, it would be possible to predict approximately the hour of the beginning of rain in Boston. Prof. F. E. Nipher had already suggested the possibility of this in the case of thundershowers, but we found it possible to follow and to predict the progress of rain at all times of the year.

The manager of the Bell Telephone Co. of Boston was approached on the subject of making a trial of a scheme of forecasting rain in this way.

A submanager who was authorized to consider the project reported favorably on the plan, but no action was authorized by the directors.

Later Mr. Fox interviewed the Telephone Co. of New York on the same project without success.

I still consider the plan a feasible one, however, and it only wants energetic action by a sufficiently powerful organization to insure its success.

RELATION OF WINDS TO TEMPERATURE IN CENTRAL OHIO.

By HOWARD H. MARTIN, Observer.

[U. S. Weather Bureau, Columbus, Ohio, Mar. 22, 1920.]

SYNOPSIS.

This paper presents by table and graph the existing relation between the direction of the wind and the existing or current temperature, as well as the subsequent 24-hour temperature change. The data are taken from the records of the Columbus (Ohio) office, 1909–1918, inclusive.

It is a fact of common knowledge that some winds are warmer than others, yet it is not generally known that from certain directions, in central Ohio, winds are cooler during the entire year than from others. A glance at figure 1 will reveal this difference, for during all seasons winds from the north and the northwest are accompanied by lower temperatures than from any of the other directions, and also it is evident that winds from the south are warmer than from other directions. The southeast wind may be classified as a warm wind during most of the year, but is cooler than the average of all directions during the summer months. The east wind, too, is much cooler in the summer months, relatively speaking, than during the autumn and winter months.

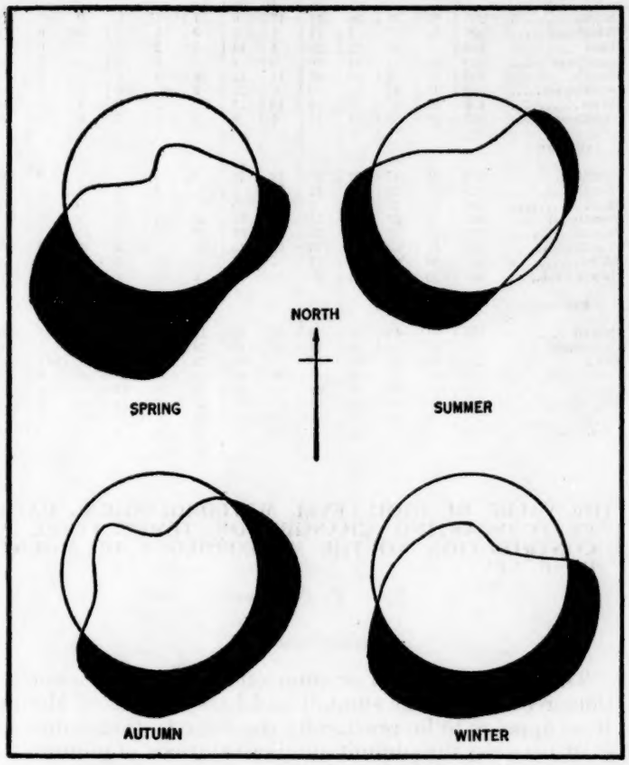


FIG. 1.—Showing the relation between the prevailing direction of wind at 7 a. m. and 7 p. m. and current temperature, Columbus, Ohio, 1909–1918, inclusive. Warm winds represented by that portion in solid black outside of circle; cold winds by that portion inside. (Scale: 1 inch radially equals 20° F.)

Table 1 shows the average temperature at the semi-daily observation hours, arranged according to the direction of the surface wind at that time. Thus it will be seen again that the north wind for the year is cooler and the south wind warmer than the average. It is to be noted, however, that during the winter months central Ohio experiences the coldest weather with the northeast wind, changing to the northwest in the spring, and to the north in the summer and autumn. During the winter the higher temperatures accompany the southeast wind, changing to the south in spring, to the southwest in summer, and back to the south in the autumn.

There also exists a relation between the direction of the surface wind and the subsequent 24-hour temperature change. That is to say, certain winds may be considered as fair prognostics of colder weather or of warmer weather. Thus, considering figure 2, it will be seen that during the spring months, the southeast, east, northeast, and north directions are followed by warmer weather, the northwest being practically neutral or without prognostic value, while all other directions presage cooler conditions. During the summer the east wind loses its prognostic value. During the autumn the northwest wind becomes a harbinger of cooler weather, while the east wind again precedes warmer atmosphere. In the winter, it is to be noted, any easterly direction from south to north may be considered as of fair prognostic value indicating increasing temperatures, while all westerly directions indicate lower temperatures.

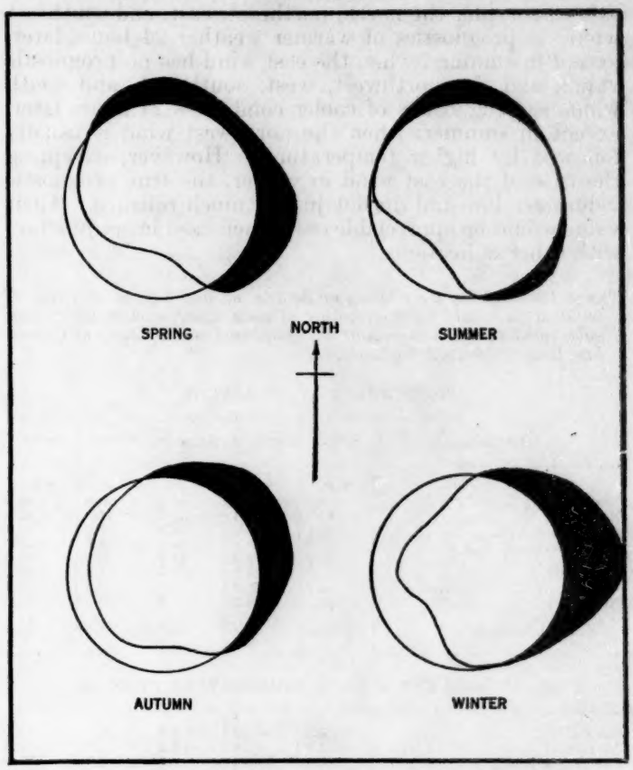


FIG. 2.—Showing the relation between the prevailing direction of wind at 7 a. m. and 7 p. m. and subsequent 24-hour temperature changes, Columbus, Ohio, 1909–1918, inclusive. Positive changes represented by that portion of wind rose outside of circle; negative changes by that portion on inside. (Scale: 1 inch radially equals 20° F.)

Table 2 merits careful consideration. It shows the number of times temperature changes, positive and negative, have occurred during the ten years, 1909–1918, inclusive, during the 24 hours following the observation of a given direction of surface wind. Of course, in no case is the prognostic value sufficiently high to warrant implicit

confidence in the wind directions as temperature indicators, but the figures show that there does exist a relation. Especially important is the fact disclosed in Table 2 that of the 32 winter temperature falls equaling or exceeding 30° during the 10-year period in question, 21 occurred following the west and southwest winds. Cold waves during winter months with temperature falls exceeding 20° occurred 123 times, and 85 of these occasions followed a westerly wind. It is also noteworthy that during the winter months 26 of the 123 temperature falls equaling or exceeding 20° followed the southeast wind, normally an indication of higher temperature. This fact was brought about by the passage of rapidly moving LOWS, far in excess of normal speed, and the temperature rise as well as the subsequent cold wave occurred within the 24-hour period.

Under ordinary conditions, at Columbus, Ohio, it seems safe to consider the north, northeast, east, and southeast winds as prognostics of warmer weather 24 hours later, except in summer, when the east wind has no prognostic value; and the northwest, west, southwest, and south winds as prognostics of cooler conditions 24 hours later, except in summer, when the northwest wind is usually followed by higher temperatures. However, excepting the case of the east wind in winter, the true prognostic values are low and do not justify much reliance. Their value would be appreciable only when used in conjunction with other indications.

TABLE 1.—*Showing the relation of the 7 a. m. and 7 p. m. direction of wind to the actual air temperature at those hours, and to the average subsequent 24-hour temperature changes, based on the records at Columbus, Ohio, 1909–1918, inclusive.*

TO CURRENT TEMPERATURE.

Direction.	Spring.	Summer.	Autumn.	Winter.	Annual.
	° F.	° F.	° F.	° F.	° F.
North	44.5	63.8	46.5	23.0	44.5
Northeast	46.4	70.4	52.6	21.8	47.8
East	53.1	70.6	56.8	30.6	52.8
Southeast	52.2	68.6	56.2	32.8	52.5
South	58.7	72.5	57.7	32.5	55.4
Southwest	57.6	74.7	55.7	31.6	54.9
West	48.4	72.1	49.5	26.1	49.0
Northwest	41.4	66.3	47.9	23.8	44.8
Mean, seasonal	50.3	69.8	52.8	28.0	50.2
TO SUBSEQUENT 24-HOUR TEMPERATURE CHANGES.					
North	+3.3	+2.2	+1.3	−0.7	+1.9
Northeast	+2.4	+0.4	+4.1	+5.3	+3.1
East	+4.4	+0.1	+3.4	+7.9	+3.9
Southeast	+2.6	+1.6	+1.7	+2.0	+2.0
South	−4.0	−0.5	−2.4	+1.1	−1.5
Southwest	−2.6	−4.4	−1.6	−3.4	−3.0
West	−2.0	−0.5	−1.8	−1.6	−1.5
Northwest	+1.5	+0.3	−1.1	−2.0	−0.3
Seasonal mean	+0.7	0	−0.4	+1.2	+0.6

TABLE 2.—*Showing the number of times various wind directions were followed by positive or negative temperature changes, arranged according to the seasons, Columbus, Ohio, period 1909–1918, inclusive.*

Direction.	Number times noted.	6 degrees or more.		8 degrees or more.		10 degrees or more.		15 degrees or more.		20 degrees or more.		30 degrees or more.	
		+	−	+	−	+	−	+	−	+	−	+	−
SPRING.													
North	235	61	15	52	9	40	2	14	0	1	0	0	0
Northeast	131	34	13	18	8	12	2	4	0	0	0	0	0
East	159	62	7	33	2	20	0	18	0	3	0	0	0
Southeast	253	131	62	108	48	80	44	36	30	7	7	1	1
South	226	41	97	30	81	19	76	13	39	4	10	0	2
Southwest	214	32	84	27	60	18	54	11	28	6	18	0	2
West	214	30	68	28	47	10	25	3	14	0	4	0	1
Northwest	317	78	63	62	40	53	28	20	15	3	4	0	1
SUMMER.													
North	235	62	23	30	13	17	6	7	1	1	0	0	0
Northeast	199	13	17	5	11	1	3	0	1	0	0	0	0
East	194	20	28	12	23	4	14	0	2	0	1	0	0
Southeast	229	29	17	14	10	6	4	3	1	0	0	0	0
South	320	25	53	19	43	11	17	6	8	1	1	0	0
Southwest	280	17	87	12	59	8	27	2	15	0	5	0	0
West	150	37	27	18	24	10	13	2	7	0	1	0	0
Northwest	213	20	29	13	18	6	9	2	2	0	0	0	0
AUTUMN.													
North	174	41	47	21	31	12	26	4	8	0	3	0	0
Northeast	129	46	21	26	12	19	8	11	5	3	1	2	0
East	200	90	21	72	7	51	5	32	1	17	0	8	0
Southeast	301	75	38	58	35	37	30	18	23	7	11	0	0
South	287	40	88	35	74	25	66	17	41	3	25	1	9
Southwest	245	38	68	28	59	22	42	13	31	2	16	0	5
West	241	24	97	21	74	17	53	7	34	3	16	0	3
Northwest	238	23	31	17	25	11	17	7	13	1	7	0	2
WINTER.													
North	156	31	44	26	28	22	13	15	7	6	3	1	0
Northeast	78	31	24	28	14	22	10	13	4	6	1	1	0
East	123	65	20	55	15	47	10	33	3	19	0	2	0
Southeast	275	142	72	126	57	105	48	58	36	31	26	6	3
South	272	108	104	82	62	63	50	29	26	14	8	1	4
Southwest	280	90	104	76	97	67	68	35	65	14	32	3	11
West	318	88	129	72	98	62	74	26	46	8	35	0	10
Northwest	289	37	85	26	74	16	62	6	33	0	18	0	4

THE VALUE OF HIGH-LEVEL METEOROLOGICAL DATA IN FORECASTING CHANGES OF TEMPERATURE—A CONTRIBUTION TO THE METEOROLOGY OF MOUNT ROSE, NEV.[1]

By S. P. FERGUSSON.

[Author's summary.]

The general relation or connection between the conditions recorded at the summit and base stations of Mount Rose appears to be practically the same as that found to exist between the summit and base stations of mountains in other parts of the world.

Of the decided falls of temperature or cold waves occurring on the summit during four years of observa-

[1] Reprinted from Technical Bulletin No. 83, University of Nevada Agricultural Experiment Station, Reno, Nev., 1915, pp. 29 and 30.

tion, about one-half were accompanied by nearly synchronous changes at the base stations; one-third were followed within 48 hours by lower minimum temperatures at the base stations; one-fifth were followed by a slight rise of temperature at the base stations.

In the instances where cold waves on the summit precede those at the base, particularly those where a rise of temperature occurs at the base, the cause is probably local gradients less steep than usual, mechanical cooling of the air at the summit during a strong wind, or clouds or fog in the valleys and below the summit. Such a condition, however, does not appear to be a very stable one and probably can not exist very long.

Abnormal falls of temperature or cold waves occur most frequently when a cyclone or area of low pressure is about 500 miles south or southeast, and an anticyclone or area of high pressure about 300 miles northwest of Mount Rose.

When well-defined cyclones and anticyclones pass over or near Mount Rose, the changes of temperature at the summit and base are nearly synchronous, for at such a time the winds at all levels are higher than normal and the atmosphere more nearly homogeneous.

It is believed that data from high-level stations will be found valuable in local forecasting when studied with reference to the prevailing meteorological conditions, as shown by the daily weather maps. However, since the processes of the free atmosphere are not as yet fully understood, particularly in this region where no systematic aerological exploration has been made, it will be necessary first to determine the vertical gradients or distribution of the chief meteorological elements by means of recording instruments elevated by kites and balloons and from observations of the formation and movements of clouds. This work should be done in some level region, such as the Carson Sink, where the phenomena of the free atmosphere are not influenced by neighboring mountains or valleys. Comparisons of free-atmosphere data with observations on mountains and in valleys under various conditions of weather will show the relation of local phenomena to the general movements of the atmosphere.

Practical use of the results of an investigation of this kind can be made by embodying the information in courses of study, and in publications, so that, in time, the residents of any community familiar with local conditions and having access to the daily weather maps will be able to make local forecasts more accurate than those based upon local or general data alone.

The writer believes that the local weather maps could be improved by the use of data from a larger number of stations and by reducing the data to the average level of the region as well as to sea level, for thereby where changes of pressure are small the effects of errors of reduction will be lessened. Further improvement could be effected by adopting the plan of the International maps wherein the pressures are published in C. G. S. units, so that the pressure at any level is a direct percentage of the entire standard atmosphere near sea level.

The Weather Bureau is rendering an important service in publishing maps, forecasts, and general information for the benefit of agriculture, and this can be made much more effective if our agricultural colleges and stations cooperate with courses of instruction and intensive investigation of problems of local interest.

AEROLOGICAL OBSERVATIONS DURING AIRPLANE FLIGHT ABOVE HAWAIIAN ISLANDS.

[Abstract of report by Lawrence H. Daingerfield, Meteorologist, Weather Bureau, Honolulu, Hawaii.]

This flight was made from Luke Field, Oahu, Hawaii, between 11 and 11:45 a. m., February 25, 1920. Readings of a sling psychrometer were made for each thousand feet during the ascent and descent, and cloud and wind conditions were also noted. Altitudes were those indicated by a standard altimeter, no corrections being applied for mean temperature of the air column.

A light westerly wind prevailed at the surface; this gave way at a low altitude to the northeast trade wind, which in t rn was displaced by a strong west wind (antitrade) at an altitude of about 11,000 to 12,000 feet.

Cumulus clouds were entered at an altitude of 3,000 to 4,000 feet; above these clouds the sky was partially obscured by alto cumulus and a veil of alto stratus from the west.

Psychrometric observations were made by exposing the dry and wet bulb thermometers to the air rushing by the upper left-hand surface of the fuselage. These observations showed decreasing temperatures and relative humidities to the base of the cumulus; a continued temperature decrease and a rise in humidity from that level to the top of the cumulus; a temperature inversion and very low humidity during the next 2,000 feet; and decreasing temperatures, accompanied by increasing humidities, from about 8,000 feet to the highest altitude reached.

So far as known, these are the first free-air meteorological observations ever made above the Hawaiian Islands.—*W. R. G.*

ALTITUDE DETERMINATIONS BASED ON BAROMETRIC READINGS.

By H. G. CORNTHWAITE, Acting Chief Hydrographer.

[Balboa Heights, Canal Zone, Mar. 16, 1920.]

Under favorable conditions very accurate altitude determinations can be made from simultaneous barometric readings, especially in the Tropics where air-pressure fluctuations are small.

Up to elevations of 5,000 or 6,000 feet a mercurial barometer is preferable to an aneroid for this work if closely accurate results are desired; at higher levels it will probably be necessary to use an aneroid, which should give satisfactory results if the instrument used is a good one, but it should first be carefully tested covering the expected range in pressure readings. Few aneroids can be depended upon to give as accurate readings over a wide range in pressure as a good mecurial barometer. The aneroid may read accurately at sea level, but be off several hundredths of an inch at an elevation of 5,000 feet. When it is recalled that an error of 1/100 inch is equivalent to about 10 feet difference in altitude, it will be seen that an error of a few hundredths inch in the aneroid reading may mean a considerable error in the altitude determination.

A "Mountain" mercurial barometer equipped with carrying case and tripod is a convenient instrument to use for topographic reconnaissance work at moderate elevations, and it will give better results than most aneroids (see plate No. 1).

Best results are obtained when simultaneous readings are made at a near-by station of known elevation at the base of the hill or mountain.

The average of three or more simultaneous readings taken at 15 minutes or half hour intervals ordinarily will give better results than can be obtained from single readings.

If the base station is located near by and all readings are accurately made it should be possible to figure the difference in elevation very closely, using reduction tables such as those published in "Smithsonian Meteorological Tables." It is important to record the attached thermometer and shade air temperatures also, for use in correcting and reducing the readings.

In the Tropics where the air is warm and light one inch difference in air pressure is equivalent roughly to 1,000 feet difference in altitude, while in the temperate zone where the air is cooler and denser an inch difference in pressure may equal only 850 or 900 feet difference in altitude. For this reason the arbitrary fixed altitude scales on aneroids are not reliable for varying temperature conditions.

If it is not possible to take simultaneous readings at a near-by base station, the pressure at the lower station must be estimated. Under these conditions less accurate results will be obtained.

The accompanying plate (No. 2) shows typical winter pressure curves for temperate zone and tropical climates. The large irregular pressure fluctuations in the temperate zone make it extremely difficult to determine elevations accurately from barometric readings unless simultaneous readings at a near-by base station can be made.

In the Tropics the barometric pressure is so constant, except for regular, well-marked diurnal fluctuations, that the sea-level pressure can be estimated closely, and fairly good altitude determinations can be made without taking simultaneous pressure readings at a near-by base station.

The following results were obtained in the Canal Zone, elevations being determined from the average of six mercurial barometer readings taken simultaneously at the upper and lower stations.

Station.	Elevation by barometer.	Actual elevation by triangulation.
	Feet.	*Feet.*
Ancon Hill	659	654
Cerro Gordo	965	972

It will be seen that the elevations obtained by barometer were off less than 1 per cent (assuming the elevations by triangulation to be correct).

Individual readings varied but slightly from the mean of all readings, as may be seen from the following table:

Time.	Corrected station pressure.		Indicated difference.	Indicated altitude of Ancon Hill.[1]
	Ancon.	Ancon Hill.		
	Inches.	*Inches.*	*Feet.*	*Feet.*
1:45 p. m.	29.638	29.078	562	654
2:00 p. m.	29.641	29.077	568	660
2:15 p. m.	29.641	29.078	567	659
2:30 p. m.	29.640	29.071	573	665
2:45 p. m.	29.641	29.083	559	651
3:00 p. m.	29.638	29.069	573	665
3:15 p. m.	29.631	29.067	565	657
Average of all readings				659

[1] Difference in feet plus 92 feet (elevation of Ancon Station).

These determinations were made under the most favorable conditions, the base station at Culebra being not more than 2 miles distant from Cerro Gordo, and the base station at Ancon less than a mile distant from Ancon Hill. Actual field work would often have to be performed under less favorable conditions, with base stations farther distant or unavailable, in which case less accurate results would be obtained.

COMPARISON OF SNOW-BOARD AND RAINGAGE-CAN MEASUREMENTS OF SNOWFALL.

By ROBERT E. HORTON.

[Voorheesville, N. Y., Mar. 17, 1920.]

The unusual accumulation of snow in eastern New York afforded an opportunity for comparison of the accuracy of measurements of snowfall by two different methods in common use. The rain gage overflow can and the snow board were both exposed on the ice near the center of a pond at the author's laboratory, the pond being about 100 feet wide and several hundred feet in length, in an easterly and westerly direction. The north slope to the pond ranges from 10 to 20 feet per hundred, and the pond is bordered on the north by occasional trees and brush. The south bank is abrupt and wooded. Snow drifts on the pond surface only on rare occasions.

The snow board used was that devised by the author, consisting of a sheet of white beaver board, about 16 inches square, with a layer of cotton flannel tacked on to the surface of the beaver board, nape uppermost. After each reading was taken, the snow board was cleaned and dried, and laid on the surface of the newly fallen undisturbed snow. In all the storms recorded in the table, the snow fell mainly during wind, and at a large angle to the vertical, often approaching the horizontal.

Comparing the results as shown in column 5, it will be noted that the average depth of snowfall, as determined by the water equivalent, is 16 per cent more than that determined from measurements taken in the overflow can of the rain gage. In taking the readings, the gage can was first weighed, the snow then removed therefrom, and a sample cut out of the snow on the snow board by inverting the gage can over the snow board, like a cookie cutter, then picking up gage can and snow board together, so as to get a perfect sample in the gage can. The gage can was then again weighed. An accurate torsion balance was used, making possible in all cases to determine the water equivalent of the snow to the nearest thousandth of an inch of water.

It will be noted that in very light snow flurries, the amount caught on the snow board might be equal to or less than that caught in the gage can. In all heavier snows, the catch on the snow board was greater, and by a fairly consistent percentage. Much of this snow fell when the temperature was about 32°, and while the type of snow board used was specially designed to simulate a snow surface, and prevent melting, the results indicate that in very light snow flurries the snow board may give deficient results. The most significant result is, however, the fact that for two months taken as a whole, the excess indicated by the snow board is 16 per cent as compared with gage-can measurements. This on a total winter's snow precipitation of 12 inches amounts to roundly 2 inches, a fact which, if generally true, helps to afford an explanation of the apparent deficiency of winter water losses, often observed by comparison of precipitation and runoff on streams where the runoff records appear to be above suspicion.

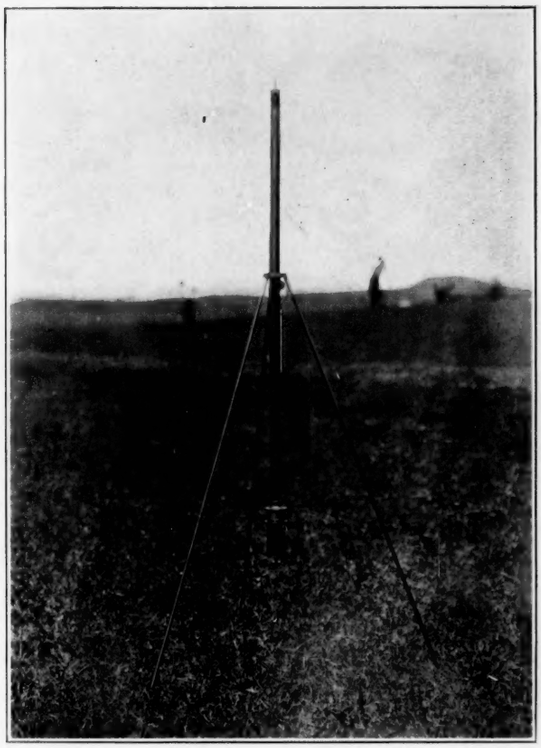


FIG. 1.—"Mountain" barometer and tripod, for use in determining elevations.

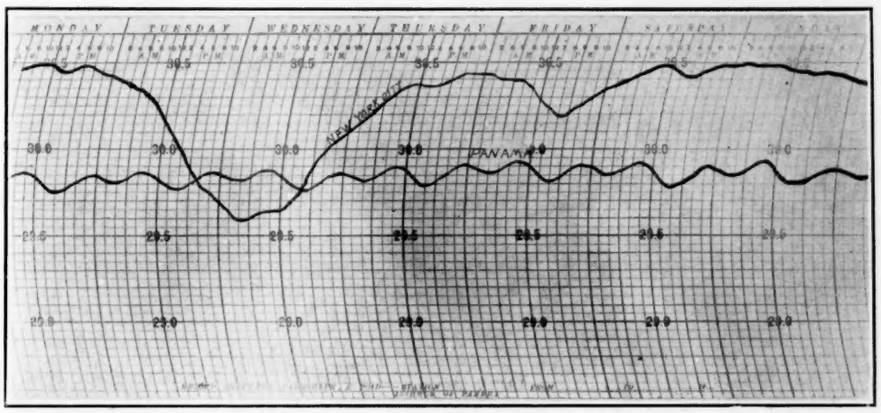


FIG. 2.—Typical winter atmospheric-pressure curves for a 7-day period at New York City and at Panama.

FIG. 1.—Overflow can and snow board. (A, snow board.)

Comparison of snowfall measured by standard rain gage overflow can and by snow board. Horton Hydrologic Laboratory, 1920.

Date, 1920.	Depth on snow board.	Water equivalent of snow.		Ratio: Board can.	Total depth on ground.
		Gage can.	Snow board.		
1	2	3	4	5	6
	Inches.	*Inches.*	*Inches.*		*Inches.*
Jan. 17	5.88	0.142	0.151	1.06	.....
19	0.25	.053	.014	0.26	7.50
20	1.00	.041	.041	1.00	8.50
24	4.25	.209	.230	1.10	11.87
25	1.50	.046	.057	1.24	13.00
28	Trace.	.0087	.003	0.34	11.50
Feb. 7	8.00	.544	.600	1.10	20.13
12	0.75	.159	.193	1.21	18.37
16	3.63	.175	.302	1.73	15.00
20	0.19	.018	.018	1.00	.....
22	0.75	.022	.029	1.32	.....
24	2.38	.071	.091	1.28	.....
Total	.....	1.489	1.729	1.16	.....

ON THE COMPARISON OF METEOROLOGICAL DATA WITH RESULTS OF CHANCE.

By LOUIS BESSON, Chief, Meteorological Service of Paris.

[Translated from the French, and abridged, by Edgar W. Woolard.]

I.

Suppose we have a set of values of some meteorological element, e. g., the mean daily atmospheric pressure for N consecutive days,

$$Y_1, Y_2, Y_3, \cdots, Y .$$

If one of these values is smaller than both the preceding and the following value, then the pressure has passed through a minimum; suppose we find, in the series, M such minima: should we attribute this result to some physical cause which tends to produce M barometric minima in N days, or is it only such that it can be accounted for by the laws of pure chance? We are thus led to the problem of determining how many minima should be found in a series of N numbers obtained by chance selection. (Whatever concerns minima is equally applicable to maxima.)

This problem was investigated some time ago by Grossmann,[1] who employed the method of *variations:* Given a series of numbers, the variation of each is considered to be positive, negative, or zero, according as the following value is larger, smaller, or the same; the numerical values are then discarded, only the signs of the variations being retained. Evidently, a minimum is indicated by a negative variation immediately followed by a positive variation, or separated from the latter by any number of zero variations.

Grossmann derives the formula

$$M=\frac{ab}{N}\left[1+\frac{c}{N-1}+\frac{c(c-1)}{(N-1)(N-2)}+\cdots+\frac{c!}{(N-1)\ (N-2)\ \cdots\ (N-c)}\right],$$

where M is the number of minima which should occur in a series of N chance values, a being the number of positive variations, b that of the negative variations, c that of the zero variations. If there are no zero variations the formula becomes $M=ab/N$; and if, in addition, there are as many positive signs as negative, $M=N/4$.

In reality, the most probable number, k, of minima in a set of N variations which comprises a positive signs and b negative signs is given by

$$\frac{(a+1)(b+1)}{a+1+b+1}-1<k<\frac{(a+1)\ (b+1)}{a+1+b+1};$$

but this value is practically equal to that given by Grossmann's formula.

II.

If we assume the total number of signs to be infinitely great, it is possible to arrive, by the use of variations, at formulae for the number of minima by a method different from that employed by Grossmann. As a matter of fact, the original problem has no meaning unless we are dealing with a very long series, for the laws of chance are applicable to large numbers only.

Suppose, then, that a sack contains an infinite number of balls marked with positive, negative, and equality signs, in such proportions that for any N balls there will be on the average a positive signs, b negative, and c equality. The total number of balls being infinite, the proportions of the three kinds remaining in the sack after a drawing has been made, no matter how many may already have been drawn, continue to be (a/N), (b/N), and (c/N); then the chances for drawing a positive, negative, or equality sign, are respectively (a/N), (b/N), (c/N); the probability of a minimum with no equality signs therefore becomes $(a/N)\ (b/N)$, that of a minimum with one equality sign $(a/N)\ (b/N)\ (c/N)$, etc. The probability of a minimum is therefore given by

$$\frac{a}{N}\frac{b}{N}+\frac{a}{N}\frac{b}{N}\frac{c}{N}+\frac{a}{N}\frac{b}{N}\frac{c^2}{N^2}+\cdots=\frac{ab}{N^2}\left(1+\frac{c}{N}+\frac{c^2}{N^2}+\cdots\right),$$

and the number of minima is found by multiplying this probability by N,

$$M=\frac{ab}{N}\left(1+\frac{c}{N}+\frac{c^2}{N^2}+\cdots\right)$$

$$=\frac{ab}{N}\ \frac{1}{1-\frac{c}{N}}.$$

This number does not differ sensibly from that given by Grossmann, as long as N is very large. When there are no equality signs, the two formulæ become identical; however, in this case, taking account of the minima which occur complete, for two consecutive signs the probability of a minimum is of course (ab/N^2); there are $N-1$ pairs of consecutive signs, and the number of minima becomes

$$M=(N-1)\frac{ab}{N^2}.$$

If there are no equality signs in the series, then the shortest possible interval between two consecutive minima is that where the two signs forming a maximum occur between the two signs indicating the minima, thus: $-\ +\ -\ +$. We shall call this a *two-interval;* the probability of the occurrence of such a grouping is $\frac{a^2\,b^2}{N^4}$, and in a set of N signs the probable number of times it should occur would be given by $(N-3)\frac{a^2\,b^2}{N^4}$, since there are $(N-3)$ sets of four consecutive signs. Similarly, the next

[1] L. Grossmann, Die Aenderung der Temperature von Tag zu Tag an der deutschen Kuste, aus dem Archiv der Deutschen Seewarte, XXIII Jahrgang, 1900, pp. 34-37.

largest interval, the *three-interval* is caused by either of the groupings $-++-+$, $-+--+$, and hence its probability is

$$\frac{a^3b^2}{N^5}+\frac{a^2b^3}{N^5}=\frac{a^2b^2}{N^4}\left(\frac{a+b}{N}\right)=\frac{a^2b^2}{N^4},$$

or the same as that of the two-interval, and the probable frequency becomes $(N-4)\frac{a^2b^2}{N^4}$.

The *four-interval* is brought about by any one of the three groupings, $-+++-+$, $-+---+$, $-++--+$. The probability is

$$\frac{a^4b^2}{N^6}+\frac{a^2b^4}{N^6}+\frac{a^3b^3}{N^6}=\frac{a^2b^2}{N^4}\ \frac{a^2+ab+b^2}{N^2},$$

and in a set of N signs it should occur a number of times equal to

$$(N-5)\ \frac{a^2b^2(a^2+ab+b^2)}{N^6}.$$

The law of formation of these expressions is obvious: Generally, the *j-interval* should be encountered in a set of N signs a number of times equal to

$$(N-j-1)\ \frac{a^2b^2(a^{j-2}+a^{j-3}b+\cdots+b^{j-2})}{N^{j+2}}.$$

If there be equal numbers of positive and negative signs, the probabilities of the respective intervals reduce to

$$\frac{1}{2^4},\ \frac{2}{2^5}\ \left(=\frac{1}{2^4}\right),\ \frac{3}{2^6},\ \frac{4}{2^7},\ \text{etc., and their frequencies to}$$

$$\frac{N-3}{16},\ \frac{N-4}{16},\ \frac{3(N-5)}{64},\ \frac{4(N-6)}{128},\ \text{etc.}$$

III.

There is, however, a second method by which we may arrive at the formulæ required by our original problem.

Let there be a variable, y, susceptible of n different, equally probable, values, $a_1, a_2, \ldots\ldots, a_n$. Assume that y, varying by chance, takes the successive values y', y'', y'''. What is the probability of there being a minimum at y''?

Suppose, first, that n is so great that the relative frequency of the cases where $y''=y'$ or $y''=y'''$ is so small as to be negligible; then there will be a minimum when $y'>y''<y'''$. This double inequality may be satisfied in a number of different ways. If $y''=a_1$, there are $(n-1)$ possible values for y' as well as for y''' (the above series of possible values being arranged in numerical order), giving $(n-1)^2$ possible cases; if $y''=a_2$, there are $(n-2)^2$; if $y''=a_3$, there are $(n-3)^2$; etc. Finally, when y'' has the largest possible value, a_{n-1}, there is but one way of satisfying the inequality. Then the total number of possible ways in which the inequality may be satisfied is

$$(n-1)^2+(n-2)^2+\ldots\ldots+1^2$$
$$=\frac{(n-1)n(2n-1)}{6}$$
$$=\frac{2n^3-3n^2+n}{6}.$$

The probability of the occurrence of a minimum is then the ratio of the number of possible ways in which the inequality may be satisfied to the number of possible cases of different triads; this latter, since to each of the n possible values of y'' correspond n possible values of y' and also of y''', is evidently n^3. The probability therefore becomes

$$\frac{1}{3}-\frac{1}{2n}+\frac{1}{6n^3},$$

or simply $\frac{1}{3}$ if n is infinitely great; then, if y takes on a great number, N, of successive values, there will be $N-2$ *groups* of three successive values and we should find the most probable number of minima to be

$$M=\frac{N-2}{3}.$$

The formula of the method of variations gives as the number of minima

$$M=\frac{N-2}{4}.$$

As is seen, the formulæ given by the two different methods are not the same.

Consider, now, the case where y takes on several successive values which are equal to one another. A minimum remains characterized by three values which we shall continue to designate by y', y'', y''', such that

$$y'>y''<y''',$$

but now y'' is repeated λ times.

The number of possible ways in which the inequality may be satisfied is always

$$\frac{(n-1)n(2n-1)}{6};$$

but now to each of the n^3 possible triads correspond n^λ possible arrangements with the λ extra values of y'' included, giving as the total number of possible different groups $n^{\lambda+3}$. Giving to λ its successive possible values 0, 1, 2,....., and summing the *probabilities*, the probability of a minimum becomes

$$\frac{(n-1)n(2n-1)}{6n^3}\left(1+\frac{1}{n}+\frac{1}{n^2}+\cdots\cdots\right)$$
$$=\frac{(n-1)n(2n-1)}{6n^3}\ \frac{n}{n-1}=\frac{n^2(2n-1)}{6n^3}$$
$$=\frac{1}{3}-\frac{1}{6n}.$$

It is sufficient to multiply this probability by N in order to get the most probable *number* of minima one should encounter in a set of N values of y; this follows from the mathematical definition of probability. Then when n is infinitely great the *probability* is $\frac{1}{3}$, the same as found before.

FREQUENCY OF VARIOUS INTERVALS BETWEEN TWO CONSECUTIVE MINIMA—SECOND METHOD.

Assume, first, that n is so great that we may neglect the minima in which several equal values occur.

Minimum followed by a given value.—Consider the group of three consecutive values, y', y'', y''', such that $y'>y''<y'''$, and let y''' be given equal to a_p; then y'' can take any one of the values $a_1, a_2, \ldots\ldots\ldots a_{p-1}$; if $y''=a_1$, y' can take any one of the remaining

$n-1$ higher values; if $y''=a_2$, y' can take any one of the other $n-2$ values; and so on, until when $y''=a_{p-1}$, y' has $n-p+1$ possible values. The *total* number of possible arrangements is

$$(n-1)+(n-2)+\ldots\ldots\ldots+(n-p+1).$$

This sum is a function of p; it becomes equal to $(n-1)$ when $p=2$, to $(n-1)+(n-2)$ when $p=3$, etc. Let

$$(n-1)+(n-2)+\ldots\ldots\ldots+(n-p+1)=f_1(p).$$

Minimum followed by two rises, of which the second can be zero, the series ending in a given value.—Consider the group of four consecutive values, y', y'', y''', y^{iv}, such that $y'>y''<y'''<y^{iv}$, and let y^{iv} be given equal to a_p.

Now, y''' can take any of the values $a_1, a_2, \cdots a_p$. It is easily seen that the total number of possible arrangements giving us our required type of minimum is

$$f_1(2)+f_1(3)+\cdots\cdots+f_1(p).$$

Now let

$$f_1(2)+f_1(3)+\cdots\cdots+f_1(p)=f_2(p).$$

In the same way, applying the last formula to the case of a minimum followed by three rises, of which the last two may be zero, the entire series ending in the value a_p, we find as the total number of possible ways in which such can be effected

$$f_2(2)+f_2(3)+\cdots\cdot f_2(p)=f_3(p);$$

and, generally, for a minimum followed by q rises, the last $q-1$ of which may be zero, the series ending in the value a_p, this number is

$$f_q(p).$$

The same reasoning evidently applies to a minimum preceded by q rises, the first $q-1$ of which may be zero, the initial value being a_p.

The value of $f_1(p)$ can readily be calculated with the help of the well-known formulas for the sums of the first n integers, their squares, cubes, etc.

We have

$$f_1(p)=\frac{-p^2+(2n+1)p-2n}{2};$$

$$f_2(p)=\Sigma_2^p f_1(p)$$

$$=\frac{-\Sigma_2^p p^2+(2n+1)\Sigma_2^p p-2n(n-1)}{2}$$

$$=\frac{-p^3+3np^2-(3n-1)p}{6};$$

$$f_3(p)=\frac{-p^4+(4n-2)p^3+p^2-(4n-2)p}{24},$$

etc.

The probabilities of the various intervals can now be calculated.

The two-interval.—In the notation of the method of investigation now being employed, the *two-interval* is given by a group of five consecutive values, y', y'', y''', y^{iv}, y^{v}, which satisfy the conditions

$$y'>y''<y'''>y^{iv}<y^{v}.$$

A minimum immediately follows and precedes y''' simultaneously.

If $y'''=a_p$ the total number of possible ways of satisfying the above conditions is $[f_1(p)]^2$; but y''' can take any of the values $a_2, a_3, \cdots a_n$; hence the total number of possibilities becomes

$$\Sigma_{p=2}^{p=n}[f_1(p)]^2=\Sigma_{p=2}^{p=n}\frac{[(2n+1)p-p^2-2n]^2}{4}$$

$$=\frac{1}{30}(4n^5-10n^4+10n^3-5n^2+n).$$

The total number of possible sets of five values being n^5, the probability of a minimum of this type is

$$\frac{1}{30}\left(4-\frac{10}{n}+\frac{10}{n^2}-\frac{5}{n^3}+\frac{1}{n^4}\right),$$

or, since n is assumed indefinitely large, simply 2/15. Since in a set of N values of y there are $N-4$ groups of five values, the most probable number of two-intervals is

$$\frac{2}{15}(N-4).$$

The three-interval.—This interval is characterized by a group of six consecutive values which satisfy the conditions

$$y'>y''<y''',$$

and

$$y^{iv}>y^{v}<y^{vi}.$$

Between the two minima we may have a rise and two falls, or two rises and a fall; the second of the two rises and the first of the two falls may be zero.

We now get as the number of ways in which these conditions can be met

$$\Sigma_{p=2}^{p=n}f_1(p)f_2(p)+\Sigma_{p=2}^{p=n}f_2(p)f_1(p)$$

$$-\Sigma_{p=2}^{p=n}[f_1(p)]^2.$$

The negative term represents the number of cases in which $y'''=y^{iv}$, these being counted twice in the preceding terms; it is negligible in comparison with the others because it gives a polynomial of degree 5 in n, and when the above expression is divided by n^6 to get the probability of the three-interval the quotient becomes zero when n becomes indefinitely great. The probability sought for is therefore the coefficient of the term in n^6 in the expression

$$2\Sigma_{p=2}^{p=n}f_1(p)f_2(p).$$

The value can, however, be found at once without calculation by noting that because of the mutual independence of y''' and y^{iv} the probability of the three interval is simply the square of that of a minimum, or 1/9; then in a set of N values, one should find $\frac{1}{9}(N-5)$ three intervals.

Now consider $j+3$ successive values of y, of which each may be indifferently $a_1, a_2, \ldots\ldots, a_n$, thus making in all n^{j+3} possible sets. How many of these possible sets will have minima in y'' and in y^{j+2}, and only in those places?

Between the two minima separated by the j-interval there can be one rise and $j-1$ falls, two rises and $j-2$ falls, and so on up to $j-1$ rises and one fall; any of these may be zero with the exception of the first rise and the last fall.

The various cases furnish in all a number of possibilities given by

$$\Sigma_{p=i}^{p=n}(f_1 f_{j-1}+f_2 f_{j-2}+\cdots\cdots+f_{j-1}f_1),$$

in which the terms equidistant from the ends are equal. The probability of the j-interval is obtained by dividing this expression by n^{j+3}.

Strictly speaking, some cases are counted several times in the above formula, viz, those in which the highest value between the two minima is repeated several times; it is easily seen, however, that if n be very large, the number of such cases is negligible relatively to that of the others; and that for n infinite, the *probability* of the interval is given simply by the coefficient of n^{j+3} in the polynomial in n by which the above sum is expressed.

It is perfectly practicable to calculate the value of this development; the computations for the intervals four, five, six, seven, and eight give for the respective *probabilities*

$$\frac{2}{35}, \frac{1}{45}, \frac{4}{567}, \frac{1}{525}, \frac{2}{4455}.$$

Therefore, in a series of N values of y, there should be found

$\frac{2}{35}(N-6)$ *four-intervals,*
$\frac{1}{45}(N-7)$ *five-intervals,*
$\frac{4}{567}(N-8)$ *six-intervals,*
$\frac{1}{525}(N-9)$ *seven-intervals,*
$\frac{2}{4455}(N-10)$ *eight-intervals.*

These results are in complete disagreement with those reached by the method of variations. We shall investigate the probable cause of the discrepancy later on.

IV.

All of the preceding work refers to the case where the various possible values of y are equally likely to occur.

Suppose, however, that the variable y satisfies the well known law of Gauss or Normal Error Law; i. e., if a be the mean value, and

$$z=y-a,$$

then the probability of a value of y being such that z is comprised within the limits z and $z+dz$ is

$$\frac{h}{\sqrt{\pi}}e^{-h^2z^2}dz,$$

h being a constant peculiar to the variable.

The probability of a value z'' being preceded by a greater value z' is evidently given by

$$\frac{h}{\sqrt{\pi}}\int_{z''}^{+\infty}e^{-hz'^2}dz'.$$

Put

$$\frac{h}{\sqrt{\pi}}\int e^{-h^2z^2}dz=u,$$

$$\frac{h}{\sqrt{\pi}}\int e^{-h^2z'^2}dz'=u',$$

$$\frac{h}{\sqrt{\pi}}\int e^{-h^2z''^2}dz''=u'',$$

etc.

It is known that the indefinite integral u has the value $\frac{1}{2}$ for $z=+\infty$, and $-\frac{1}{2}$ for $z=-\infty$. The probability sought for may be written

$$u'_{+\infty}-u'',$$

or

$$\tfrac{1}{2}(-2u''+1).$$

Now let us denote by P_1 the probability that a value z''' will be preceded by a fall which is itself preceded by a rise, or in other words that z''' will be preceded by a minimum in z''. We have just calculated the probability of a value z' preceding a lower value z''; the probability of a value falling between the limits z'' and $z''+dz''$ is

$$\frac{h}{\sqrt{\pi}}e^{-h^2z''^2}dz'', \text{ or } du''.$$

In order to fulfill the conditions of our problem, z'' can take on any value between z''' and $-\infty$; hence, the probability sought for will be given upon multiplying together the two above probabilities and summing from $-\infty$ to z''':

$$P_1=\int_{-\infty}^{z'''}(\tfrac{1}{2}-u'')\,du''$$

$$=\tfrac{1}{8}\,(-4u'''^2+4u'''+3).$$

Denoting by P_2 the probability that a value z^{iv} will be preceded by a minimum in z''' followed by two rises, we find in the same manner

$$P_2=\tfrac{1}{48}(-8u^{iv3}+12u^{iv2}+18u^{iv}+5).$$

We see that this last expression can be deduced from the preceding one by multiplying the numerical factor by 1/6, and the coefficients of the terms in the polynomial by 6/3, 6/2, and 6/1, then annexing the final term,5.

If we work out the problem of the probability P_3 of a minimum followed by three rises, the numerical factor of P_2 is multiplied by 1/8, the coefficients by 8/4, 8/3, 8/2, 8/1, and the final term is 7.

We can easily determine the law of formation of these expressions:

In the expression giving P_{i+1}, the numerical factor is equal to the product of that of P_i by $\frac{1}{2i+2}$; the coefficients of the terms in u are equal to those in P_i multiplied by the fractions which have for numerators $2i+2$, and for denominators the successive integers decreasing to 1; the final term is $2i+1$.

It may be remarked that the probability of a value z being followed by i falls, then by a minimum, is the same as the probability of a value z being preceded by a minimum and i rises.

The probabilities of a minimum and of various intervals between minima may now be found.

The probability of a value falling between z and $z+dz$ is du; the probability that this value will be preceded by a fall, itself preceded by a rise, is

$$P_1=\tfrac{1}{8}\,(-4u^2+4u+3)$$

Multiplying the two probabilities together, then summing from $-\infty$ to $+\infty$, since z has this range of values, the probability of a minimum becomes

$$\tfrac{1}{8}\int_{-\infty}^{+\infty}(-4u^2+4u+3)\,du$$

$$=\tfrac{1}{2}.$$

Thus, the probability of a minimum does not depend upon h, and it is the same as in the case where all the values have equal probabilities.

Reasoning as before, we find that the probability of two consecutive minima being separated by the j-interval is given by the expression

$$\int_{-\infty}^{+\infty}(P_1 P_{j-1}+P_2 P_{j-2}+\cdots\cdots+P_{j-1} P_1)du.$$

If the calculations be carried out, and j given successively the values 2, 3, ... etc., the same numbers are found as before. The same formulæ for the number and the distribution of minima, therefore, apply to both a variable which obeys the law of Gauss and one of which all values are equally probable.

V.

Three different tests of both sets of formulæ were carried out by counting the minima in sets of numbers which clearly were obtained by pure chance. The results left no doubt but that Grossmann's formulæ were in error, and that those of the second method were very close to the truth. Grossmann's formulæ should not, therefore, be employed in meteorological work, for it might lead us to attribute to some systematic influence the departures which would in reality be due only to the workings of chance.

The discrepancy between the two sets of formulæ may, perhaps, be explained as follows: We are considering a variable which may oscillate between two extreme limits. After taking on a small value, it has greater chances of increasing than of further diminishing, i. e., the probability of a positive sign is greater than that of a negative sign; the opposite is true after the occurrence of a large value. In Grossmann's theory, however, the probabilities of the two signs remain constant. Therefore, however paradoxical it may seem, if a variable is increasing and diminishing purely at random, it does not follow that the succession of signs of its variations will obey the laws of chance.

Grossmann considered also the probability of more or less prolonged rises or falls, and his methods and results have been used by other meteorologists; our second method leads, however, to entirely different formulæ.

Suppose the variable follows the law of Gauss; the formulæ will also be applicable when the variable has a large number of equally probable values.

Probability of an isolated rise.—This condition is given by four consecutive values such that

$$z'>z'''<z'''>z^{iv}.$$

The probability that z''' will be preceded by a fall, then by a rise, has been calculated to be

$$P_1=\frac{1}{8}(-4u'''^2+4u'''+3).$$

The probability that, in addition, z''' be superior to z^{iv} may be obtained by multiplying P_1 by the elementary probability of z''', viz, du''', and summing from z^{iv} to∞:

$$\varphi_1=\frac{1}{8}\int_{z^{iv}}^{+\infty}(-4u'''^2+4u'''+3)du$$

$$=\frac{1}{48}(8u^{iv3}-12u^{iv2}-18u^{iv}+11).$$

Since z^{iv} can now be anything from $-\infty$ to $+\infty$, we must sum $\varphi_1\,du^{iv}$ between those limits, giving as our required probability

$$\int_{-\infty}^{+\infty}\varphi_1 du^{iv}=\frac{5}{24}.$$

Probability of a series of two rises.—Such a series is given by the grouping

$$z'>z''<z'''<z^{iv}>z^{v}.$$

The probability that z^{iv} will be preceded by a fall, then by two rises, is,

$$P_2=\frac{1}{48}(-8u^{iv3}+12u^{iv2}+18u^{iv}+5).$$

The probability that, in addition, z^{iv} will be greater than z^{v} is

$$\varphi_2=\frac{1}{48}\int_{z^v}^{+\infty}(-8u^{iv3}+12u^{iv2}+18u^{iv}+5)du$$

$$=\frac{1}{384}(16u^{v4}-32u^{v3}-72u^{v2}-40u^{v}+41).$$

Finally, as z^{v} can take on any value between $-\infty$ and $+\infty$, the required probability is

$$\int_{-\infty}^{+\infty}\varphi^2\,du^{v}=\frac{11}{120}.$$

These calculations may be extended to the higher cases with the aid of the already formed expressions for P_3, P_4, etc.

It is thus found that in a set of N values there should be found, as the most probable number,

$\frac{5}{24}(N-3)$ single rises or falls,
$\frac{11}{120}(N-4)$ series of 2 rises or falls,
$\frac{19}{720}(N-5)$ series of 3 rises or falls,
$\frac{29}{5040}(N-6)$ series of 4 rises or falls,
$\frac{41}{40320}(N-7)$ series of 5 rises or falls,
$\frac{55}{362880}(N-8)$ series of 6 rises or falls,
$\frac{71}{3628800}(N-9)$ series of 7 rises or falls.

The fractions figuring in the above table may be deduced one from another in a simple manner:

The numerators increase successively by 6, 8, 10, 12, etc., and the denominators are multiplied successively by 5, 6, 7, 8, etc. The list of probabilities can therefore easily be recalled and extended. A verification of the preceding formulæ was made.

VI.

The formulæ derived in this paper appear to satisfy all demands that can be made upon them for their application to meteorology.

For a rigorous comparison it would be necessary, in any particular case, first of all to give the mathematical variable all the characteristics possessed by the natural variable being considered, and leave undetermined only its tendency to increase or decrease in value, this last being left to the domain of chance. It is then a question whether or not our formulæ apply to a variable of the nature so determined, so that we may legitimately compare the mathematical results of chance with the observational results of experience, and decide as to the existence of a systematic influence.

It seems to the writer that the only things which it is necessary to consider in this connection are (*a*), the law of probability for the occurrence of the various possible

values, and (*b*), the mean variability, i. e., the mean difference between successive absolute values of the variable.

(*a*) Our formulæ are exact in both the very different cases where all values are equally probable and where they follow the law of Gauss, as well as in still different cases. Hence, it can not be doubted that they possess a very great degree of generality, and no matter what law which the quantities occurring in meteorological applications might follow, the application of these formulæ would not lead us into serious error; as a matter of fact, such quantities usually follow the law of Gauss quite closely.

(*b*) The successive values of the mathematical variable are independent of one another, and the mean variability is $\sqrt{2}$ times the mean departure; but for the meteorological elements, particularly for a series of successive daily values, the values are not independent, and the mean variability is usually somewhat less than the above quantity.[1] Hence we should impose on the free mathematical variable the supplementary condition that it have the same mean variability as has the element being considered; unfortunately, one encounters here a mathematical difficulty (also met with in the theory of an imperfect gas) which has not yet been surmounted.

If we arbitrarily fixed the mean variability it would amount to admitting that the probability of the occurrence of a value is a function of the preceding value, which is exactly contrary to the fundamental assumptions upon which the theory of probability rests, and according to which all our formulæ have been derived.

However, the mean variability does not play such an important rôle as it would at first sight seem to; and some simple considerations show that the introduction of a condition reducing the mean variability somewhat would not modify the indications of our formulæ.

[1] Ch. Goutereau, Sur la variabilité de la température, Annuaire de la Société météorologique de France, 1906, p. 122.

WATERSPOUTS ON THE SOUTHERN CALIFORNIA COAST.

"Visitors at the beaches (Port San Luis, Avila, Pismo, and Oceano) Sunday afternoon about 5 o'clock had the opportunity of observing," says the San Luis Obispo Tribune, "a most unusual phenomenon, that of an immense waterspout traveling at a high rate of speed toward the beach. The spout was shaped like a funnel, and is said to have been about 2,000 feet high, extending as high as the clouds and spreading out into a fine mist. The spout was first visible from Avila and Pismo when it was about 4 or 5 miles distant from the shore, and from that time traveled rapidly until it broke on the beach between Shell Beach and the old Oilport refinery.

"Fishermen who landed at Avila later in the evening stated that they had seen three spouts at one time, two of which were traveling in the direction of the Pecho and one toward Shell Beach. The largest of the spouts was one of those going toward Pecho, and probably covered about 5 acres in area, according to the fishermen."

In describing these waterspouts the San Francisco Call says:

> The phenomenon was followed by a tremendous downpour of rain. Fishermen at sea north of the port viewed the three spouts simultaneously. As they approached the shore the two larger ones mounted the headlands, but the third was diverted. It swept around the buoy and proceeded across the bay at a speed estimated to be in excess of 40 miles an hour.
>
> Water within a diameter of from 150 to 200 yards was violently agitated and appeared to be siphoned upward to a mass of clouds some 2,000 feet above. As the spout approached the shore persons near state that there was a tremendous roar. The funnel apparently detached itself from the water and was drawn gradually up into the mass of overhanging, rapidly moving, cumulo-nimbus clouds. Violent gusts of wind followed the appearance of the spouts and continued for several hours.
>
> According to J. E. Hissong, United States weather observer here, the spouts were due to the overrunning of surface air by a layer of colder air as weather control passed from an area of low to an area of high pressure.
>
> The spouts are the first to appear on this coast within the memory of the oldest inhabitant.

INFLUENCE OF THE WIND ON THE MOVEMENTS OF INSECTS.

By WILLIS EDWIN HURD.

[Weather Bureau, Washington, Jan. 6, 1920.]

The weather perhaps has more to do with the control of insect life than all other factors combined, and the significance of this meteorological aspect is varied. Cold, heat, rain, hail, humidity, drought, sunshine, electricity, and wind are factors. Temperature, rain, and wind movement are of utmost economic importance. Sudden cold and rain in early summer may more or less completely destroy the incubating or newly hatched members of what would otherwise prove to be a vast swarm of destructive crop eaters. Drought may retard or destroy numbers of insects in their metamorphoses. Frosts at the moment of appearance of the imago may wreak untold disaster to the tender brood. And prevailing winds may so accelerate or retard the direction of movement of many injurious species at the time of their seasonal advance as to cause or avert great economic disasters.

Thus the winds may upon occasions become the paramount issue of life or death for the little fliers of our fields and orchards. When we see butterflies and other large-winged, small-bodied insects fluttering hither and yon, buffeted about in the air on a windy day, the impression is strong that any extended flight of such creatures must conform with the direction of the wind. And yet the facts do not always bear out such a conclusion, since in reality the unsteady butterfly is much more capable of forcing itself against the air current than is the heavy locust or the more projectile-like beetle.

The dispersion of insects by means of winds is a matter of constantly increasing agricultural importance. It interests the farmer inasmuch as it may affect his crops; and as it affects the agricultural staples, so does it vitally interest all of us, who need to be fed and clothed. The question was formerly more discussed by the student of geographical zoology, as it affected his plan regarding the spread of a type of life from region to region within coasts or across the seas. The South American locust, for instance, is believed in some scientific circles to be descended from the survivors of an African swarm of identical genus which, following more or less passively in the steady currents of the northeast trades, succeeded in crossing the Atlantic Ocean.

The flights, or migrations, may be largely voluntary, though a good percentage are quite the opposite. In nearly all cases the winds play an important part, and most insects are likely to follow the direction of the air currents, although some are inclined to quarter the

wind or orient themselves against it in flight—sometimes, it seems, out of pure perversity. This orientation, or apparent anemotropic instinct, however, is frequently only the effort of the insect to keep itself on the wing whether poising or in flight while the wind is blowing. Many flies and midges turn to face every passing breeze, poising themselves with wings edged to the wind, and if it becomes too strong, falling to the ground.

The involuntary flights are those in which the insects are picked up bodily and carried from local haunts by the winds, as in the case of buffalo gnats, scales, gipsy moth larvæ, and mosquitoes, or the insects while migrating may be blown from their course by the strong winds of passing storms. Indeed, on some of the tropical islands, nature seems to have stepped in with a special means of protecting some of her tinier creatures. (1) She has gradually dwarfed or eliminated the wings of certain insects, and hence they are unable to fly too high and thus risk being caught in powerful winds and blown to sea.

So air movements of gale force are always a determining factor in the flights of all insects, and certain types may be swept by hurricanes from one island to another, or to a mainland where they had not previously appeared. After the southwest gales of August 26, 1901, numbers of the "blue page" moth of Trinidad were found to have been blown to the Barbados, a distance of 160 miles, and some to Dominica, still more remote. (2) Harmful insects may also be introduced, as has frequently happened in our Southern States, through the agency of the tropical storm. The Argentine pampero at its burst often carries swarms of insects along with it. Sometimes great numbers of calosoma beetles, or, in particular, the light blue dragonflies which inhabit the pampas, are found in advance of the westerly wind in La Plata and elsewhere, instinctively seeking to escape the tempest, and when caught by it are tumbled in downlike confusion by the 70 or 80 mile gale.

But while some insects are thus caught up involuntarily, others of a more helpless type instinctively place themselves in the pathway of the air current. Various insects, notably aphids, are then known to crawl to the tops of plants just before a thunderstorm, and when the first onrush of the wind occurs, drop into it and are carried to new areas, for the purpose of mating.

The sense of smell is highly specialized, hence every breeze from a neighboring food supply is sufficient to cause a flight of winged stragglers against the wind toward the agreeable scent. The plum curculio, for instance, flies to its food supply, the neighboring plum tree, against the breeze. In like manner the presence of a female moth is communicated to the male during the mating season. Many experiments along this line have been conducted. The female moth has been confined in a cage during a breezy period and of the number of male insects observed fluttering about the captive by far the greater proportion of them came to her against the wind.

In connection with the colonization instinct and the influence of the wind upon it the home-returning instinct is so pronounced that the insects will fly against head winds to gratify it. Indeed, it seems probable that the scent of the home colony may be brought to them. The veteran naturalist, Fabre, cites an instance of his own observation (3) in the case of some identified mason bees which he carried from the home swarm to a place between two and three miles distant. Upon their releas so stiff a wind was blowing from the direction of the hive that the bees could not fly aloft where they might have seen the country, but were compelled to fly low. Yet, in 40 minutes, two of the released bees had returned home laden with pollen, and 15 or 20 uninjured insects had returned by the following morning.

The flights of insects may sometimes extend over hundreds of miles, and in this way the faunal zones of many, notably locusts or so-called grasshoppers, and some bugs and beetles, have been widely extended. Immense swarms of locusts, especially, have been seen far from land over the Atlantic Ocean, floating swiftly with the northeast trade winds, and on various occasions they have been known to alight upon the sails or decks of vessels. A recent instance of this nature was reported to the Weather Bureau by Capt. B. Morthensen of the Norwegian bark *Robert Scrafton*. On the 7th of October, 1916, when in latitude 20° 57′ N., longitude 39° 28′ W., or about 1,200 nautical miles from the African coast, this vessel met with numerous specimens of the genus *Schistocerca* flying on board in a steady northeasterly wind. (4)

Nearly all naturalists and many travelers have had occasion to comment upon the power of the locust and it is unquestionably the most common example of the migratory insects. Cowan relates many a grewsome tale of the locust hordes. (5) He tells us that about the year 872 A. D., according to Wanley's Wonders, a swarm that darkened the sun visited France with the south winds from Africa. They ate all the green vegetation and were finally blown into the sea, whence they were washed ashore in great windrows and there decayed. It was estimated that one-third of the population of France died from the resulting famine and plague.

In 1649 a swarm of locusts was carried by the northeast trades from the Barbary coast to the island of Teneriffe. (6) During the passage the insects rested at night in a great heap on the surface of the water, where many drowned, but in the morning the survivors rose in a mass which glittered in the sun, and on the second day alighted upon Teneriffe. There they were fought unavailingly for two months by 7,000 or 8,000 soldiers, after which the priests tried to drive them away through penances. But in spite of all efforts directed toward its abatement the plague lasted for four months.

In the days before the practical extermination of the Rocky Mountain locust (*Schistocerca americana*) our own country was often terribly beset by this multitudinous pest. In 1855, for instance, it devastated the region around Great Salt Lake, (7) devouring all the growing crops and the prairie grass. A high wind swept the place at the end of the summer, blowing myriads of the insects into the lake, whence they were afterwards washed ashore. When Mr. Jules Remy, the traveler, arrived he saw dead locusts piled a foot high along the beach. The ensuing famine was held by the Mormons to be a "proof of the truth of their religion, because it had happened as among the Israelites, in the seventh year after their settlement in the country."

In 1878, the United States Entomological Commission published a report upon the migrations of the locusts of North America. It was there shown that Montana was a great breeding place for the *Schistocerca*, and that from this territory they descended in vast swarms to the southeastward as far as Missouri, taking all possible advantage of the comparatively infrequent northwesterly winds that blew on fair days, for the prevailing wind over much of the stretch of country along the route during the summer

season is from the southeast. On a day with favorable winds the locusts were known to fly over the prairie for a distance of 200 to 300 miles.

These creatures in common with some other insects that fly to considerable distances, are furnished by nature with large air sacs which are capable of great dilation, especially when the body cavity is empty of food. The breathing pores are also large, and the locusts may thus become fully inflated with air so that the least possible exertion is necessary to maintain themselves for hours at a time at the swarming height, especially during dry, sunny weather. On very humid days a portion of the dilatable power is lost, and the ease of flight is thus diminished.

Nearly all locusts evidently prefer to fly with the wind, since thus a flight of many hours' duration is accompanied by an inappreciable loss of energy. Then, too, they are not fashioned to fly readily against the wind. The swarms, by instinct, migrate in the direction followed by their ancestors. But before taking a general flight, if the air is calm, numbers of the insects, actuated by the same instinct, are often observed to rise evidently to determine the direction of the upper currents; if favorable to help them along their way, the migration begins, but if unfavorable, they await a more opportune morning.(8)

It has often been observed that locusts are high fliers, and they have been reported at elevations of 13,000 to 15,000 feet. At Bismarck, N. Dak., they have been noted above the cumulus clouds, and Byers tells of two swarms, one above the other, that were seen going in opposite directions with differing air currents. (9) A change of wind, it is said, will often unbalance the insects to such a degree that they will fall helplessly to the ground before they can recover their equilibrium.

But not all insects content themselves with passivity in the wind. Strange to say, it is the butterfly that has most frequently been observed flying against the wind, although it too does not disdain the friendly current. Yet, as has previously been observed, it is far more capable of making headway against a fairly strong breeze than is the apparently more powerful-winged beetle, or the locust. However, it is the method of presentation of the wing surfaces to the wind that seems to give superiority to the butterfly in this respect. This is particularly true of the *Pierids*, *Danaids*, and *Nymphalids*, which pay as little attention to the wind direction as possible during the fever of the migration flight. With coleopterous insects the condition is different, and in commenting upon the South American beetles, the naturalist Bates says: "It is an admitted fact, I believe, that the steering power of beetles is not great, whilst the horny elytra act as vanes, putting the insect at the mercy of strong winds."

In the history of butterfly migrations—and this insect is sometimes observed flying in vast clouds which reach to a great height—it is found that certain species, notably the *Pierids* of Ceylon,(10) seem invariably to fly directly against or quartering to the monsoon, some moving northward in the fall with the approach of the northeast monsoon, and others, according to some observers, moving southward in the spring when the winds of the southwest monsoon are becoming prevalent. Over Colombo incalculable numbers of white butterflies have been seen fluttering against the stiff northerly winds, and surprised witnesses have claimed that the stronger the air current the swifter is the snowy flight.[1]

In September, 1872, Marott observed at sea near Java a column of *Pyrameis cardui* fluttering boldly against the wind, impelled by their strange instinct which seeks to over-come all obstacles. They were constantly buffeted about and beaten back into the water, where they lay dead in such numbers that the sea appeared covered with bright leaves.

Swarms of butterflies have also been met with in our own country, and their movements have been tabulated with reference to the wind. On the 23d of September, 1886, at 7 a. m., Dr. Ellzey (12) saw at West River, Md., "the whole heavens swarming with butterflies." The lower insects were flying about 100 feet from the ground and the upper ones beyond the limit of vision. They were proceeding at the rate of 20 miles an hour against a stiff northeast wind.[2]

Butterflies have been seen in the North Atlantic 500 miles or more from land, and are frequently carried on shipboard in hurricanes. According to Lucas (13), while in 25° S. latitude and 1,000 miles from the coast of Brazil, he saw several species of butterflies and moths carried in light wind and rain squalls from the westward.

Many forms of insects migrate for some cause or other, but these journeys are usually taken along the path of least resistance. Over the English Channel it is not so unusual as it might seem to discover a swarm of mixed insects, winged ants, syrphus flies, sawflies, and ladybirds floating on the breeze. In White's "Natural History of Selborne," page 366, one reads an account of a shower of aphids that fell in the village on the afternoon of August, 1785, while the wind was in the east from the direction of the Kentish hop district, where the hop aphids were numerous. Similarly, dense swarms of ladybirds, or ladybugs, have come with the wind from the hop fields, where their larvæ have previously fed upon the aphids.

Valley winds, and other rising currents of air, are also determining factors. Thus Lewis relates that, while sitting on the rim of a volcanic crater in Yezo, in July, 1880, he saw beetles carried in an ascending current from the forest below, whence they were precipitated upon the heated lava. The rising air, striking full upon the expanded wings of the insects, was sufficient to carry them upward beyond their power to resist. Similarly, large numbers of ladybirds, flying for food in the elevations of Utah, California, and other Western States, are sometimes caught in the mountain winds and hurled above the snow line to their death.

A few years ago Dr. E. Everling, of Halle, Germany, tried to interest aeronauts in making observations of insects that might be found several thousands of feet in the air. (14) The doctor himself, during a balloon voyage, had found at a considerable height one butterfly which he believed had been carried aloft by a strong vertical current, since it is unnatural for such insects to rise to great heights voluntarily, unless they are forced upward by reason of being the upper members of deep swarms that extend far aloft. In all probability they may sometimes be carried to considerable elevations in thunderstorms, or they may be caught in the fairly strong convection currents which are common even to several thousand feet elevation on warm summer days over land surfaces. These currents often have an upward velocity of 5 miles or more an hour.

The economic distribution of insects, however, is the vitally important portion of the subject to all peoples; and as has developed, of the several controls, the wind is

[1] Some of the observations of butterflies "flying against the wind" may be due to a return current aloft—perhaps the occurrence was during a sea breeze.—C. F. B.

[2] The usual, southerly, overrunning wind may not have been far up.—C. F. B.

by no means the least considerable. Entomologists agree as to its value among the dispersion factors, as a prime means in spreading insects at the time when they are most susceptible to being carried. This means generally when the insect is in wing, but it is also sometimes true even of the caterpillar stage of existence, and is well known as a dominant factor in the movements of certain other minute insects that can be carried by even light air currents, and which, being able neither to crawl nor fly at will from place to place by reason of their physical limitations, are dependent upon some exterior method of transportation.

This dispersion, however, is not always advantageous to the insect nor injurious to the farmer. A cold windstorm with driving rain may almost completely destroy a thriving colony of young bugs or flies en route, or a fortuitous wind may blow it away from its natural food supply, instead of toward it, and thus cause it to starve perhaps because of sheer inability to use the plenty in its new domain. Frail insects, like the Hessian fly and the wheat midge, are especially liable to destruction in flight, although they depend upon the wind prevailing at the time when migration must take place to conduct them to the proper food supply.

Most crop-eating insects of the South are migrants and dependent upon the meteorological conditions existing at the time of their appearance. Thus it is seen that the generally prevailing southerly winds of this region in spring spread the flies, weevils, aphids, scales, and plant lice to the northward, whence it sometimes happens that they go too far and are caught unprepared for the vigorous climatic conditions which may assail and destroy them in a single night. The more northern farmer, too, may well rejoice if the hated depredator at the beginning of its peregrinations is caught by a northerly wind, as sometimes occurs, and prevented at the outset from making any further migratory attempt for that season. Webster (**15**) hinted broadly at the possibilities of conditions of this sort when he said that the prevailing southerly winds during the breeding season in spring spread the "green bug" from Texas northward. If strong north winds prevailed at this time the winged females would be driven southward, and the problem north of the Red River rendered simpler.

One of the most destructive pests of the South is the common Mexican cotton-boll weevil, which entered extreme southern Texas in 1892. Thence annually the insect spread northward and eastward until in 1917, according to the leaflets of Hunter and Pierce of the Bureau of Entomology, 488,240 square miles of the 609,540 square miles comprising the extent of the cotton belt were infested. Two of the greatest fully defined spreads of the weevil were in 1915 and 1916, largely due to the sweeping winds accompanying the hurricane of August, 1915. This storm entered Texas from the Gulf, carrying the insect westward into 29,400 square miles that had previously been free from it in the State; then in the storm's eastward progress over the already infested area of Mississippi and Alabama, scattered the pest for the first time into Georgia. Over a considerable forward portion of this Georgia area, the result of the 1915 invasion was practically unknown until the following year, when the new broods appeared. In 1919 a further immense territory of the cotton belt was invaded, and for the first time the weevil appeared in central Tennessee and southeastern North Carolina. The reason for the extraordinary spread has not yet been determined, although the generally prevailing southerly to southwesterly winds over much of this region during July and August may have been a considerable factor. Then, too, the weevils were very numerous, owing to the preceding mild winter.

Last season the forces of the Department of Agriculture were closely watching for the possible reappearance of a still more formidable pest—the pink bollworm—members of which had been swept in cotton débris from Mexico into Trinity Bay, Texas, by the 1915 hurricane. (**16**) But fortunately the insect was not found, so the menace is for the present removed.

But, apart from what we might term the sudden or catastrophic spread of an injurious insect, we have plenty of cumulative evidence of common wind dispersion. If we watch the history of the distribution of the various scale insects, including the pernicious San Jose scale of the fruit orchards, we find that the most frequent winds determine the direction of the spread. Over most of the Middle West and the Rocky Mountain section, the prevailing direction during the period of insect activity is from the southwest, and in these winds, especially during times when their velocity is increased, the scales are picked up like tiny seeds and carried to the eastward, where they may be deposited upon a heretofore uninfested host. The spread is also more rapid up a gully than down a hill, (**17**) which indicates the considerable ascensional force of the daytime and valley winds. Various experiments have been made to determine the value and extent of this spread. Sheets of tanglefoot have been placed at varying distances and heights from infested fruit orchards, and scales have been found deposited thereon at distances of several hundred feet from the trees.

Similar experiments have been conducted in parts of New England in connection with the spread of the gipsy moth in the prevailing southwesterly winds during the hatching and early larva periods. The author of a bulletin on the subject states that "the wind is almost wholly responsible for the general spread of this insect in New England," (**18**) and further shows that the larvae, which are covered with specialized long hairs and spin certain buoyant sillken webs, are carried sometimes to great distances. In the marshes near Lynn, Mass., newly hatched worms were caught in a west wind having a velocity varying from 7 to 19 miles an hour, and some deposited on a wind catch 1,833 feet distant. At various times the caterpillars have been carried by the wind from the New Hampshire shore to the Isles of Shoals, 6 miles distant. Curiously enough, in the case of this insect the female moth is unable to use her wings for flight, hence the importance of such dispersion through the medium of the caterpillar.

But in the history of the wind distribution of certain insects man and the lower animals have not escaped physically from the incursions of various types, particularly those of the order *Diptera*, through the same meteorological control, for gnats and mosquitoes have carried discomfort, disease, and death on the otherwise comforting breezes.

The buffalo gnat of the southern swamps and bayous is sometimes swept miles from its habitat. It is a bloodthirsty creature and its visits in considerable numbers on the winds have occasioned a great amount of mortality to various animals. In the days while the street cars in Memphis (**19**) were still drawn by mules, occasions have been known during the season of development of the gnat in the St. Francis bottoms on the opposite bank of the Mississippi River that a strong west wind would bring clouds of the dangerous insects into the city. At such times so great were their numbers and voracity that

they were known to stop the street cars by killing the mules in their tracks.

Like the gnat, the mosquito, usually speaking, is not in the habit of wandering of its own accord far afield, and experiments conducted by the Public Health Service near Augusta, Ga. (**20**), on marked malaria carriers, found that the maximum natural flight from congested areas was one mile, and from less abundant communities not over a half mile, though occasionally the coast mosquitoes, including the New Jersey brand, are borne inland on the wind (**21**) 20 miles or more from their breeding marshes in a single night. On various barren keys off the coast of Florida mosquitoes have suddenly appeared when the wind is right to bear them from the breeding mainland. But with a change of direction the insects quickly vanish. The Carnegie Institution has made some studies bearing upon this phase of the question (**22**). A former WEATHER BUREAU observer, Dr. George Paterson, says that while at Sand Key he occasionally observed a swarm of mosquitoes humming about near the ground, brought in by a wind from the neighboring mangrove swamps and mainland breeding grounds. At such times it was necessary to take refuge in the top of the lighthouse, 110 feet from the ground, and thus beyond the altitude of flight of the pests, to escape them.

In the history of the malarial mosquito little is said about the actual spread of the disease through the agency of the wind, but Ealand narrates one notable example (**23**), stating that while malaria is not a city disease, conditions may thrust it upon a city, as in the case of Washington, D. C. To the south of Washington at one time lay a marshy area, the Potomac Flats, in which great numbers of the anopheles bred and flourished. With the prevailing summer-night breezes from the south the denizens of the marshes, whose voluntary flights would never have taken them so far, found themselves carried lightly along during their active hours to a rich feeding ground among human beings, where they could satisfy their appetites unchecked. Thus Washington became a city of malaria, and continued as such until the reclamation of the Flats.

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EFFECT OF A FLORIDA FREEZE ON INSECTS.[1]

The disastrous Florida freeze of February 2–4, 1917, which killed or practically defoliated the citrus trees in Putnam, Volusia, and Marion Counties, and parts of Lake and Orange Counties, and heavily damaged trees in other sections of the State, was of considerable importance in "reducing the numbers of injurious pests which infested the trees." In the section where temperatures as low as 15° or 20° F. occurred the freeze or the falling and drying of the leaves nearly exterminated the rust mite and varieties of white fly and scale insects. Few adult specimens of the various species survived except on fired or otherwise protected groves or individual trees. Of the red scale it is believed that perhaps not more than 1 in 100,000 remained alive. The almost complete extermination of this species by the freeze and its reproduction to billions in six months is a most remarkable biological fact. In some instances there was no need of the usual early spraying yet, singularly enough, in most cases the normal number of insects appeared in the following summer or fall. So, as a rule, the setback in insect life, however great even over the area of maximum freeze, was only temporary.—*W. E. H.*

ANIMAL WEATHER PROPHETS.

[Reprinted from Scientific American, New York, Mar. 20, 1920, p. 324.]

"Mere superstition," so the weather authorities say, are many of the long-distance weather predictions based on the conduct of animals. No one, so far as we know, has compiled a record of these so-called omens, but their number is multiple. They are based on a belief that animals are able to tell months in advance, for example, the character of the coming winter. If hunters bring a story to the effect that squirrels have made heavy stores of nuts, it is taken to mean that a severe winter impends. If early caught fur-bearing animals have a heavy, thick coat, that is another sign of a severe winter, or a thin coat, the contrary. If bird migrations are delayed after the usual date of the southward flight, a sign is seen of an open winter. Numerous other beliefs based on fancied ability of animals to foresee weather conditions months ahead, and base their preparations on them, have wide currency. Sometimes signs are taken from the vegetable world, as for example, the past fall in the Middle West. Corn husks, it was related, were much heavier than usual—that meant a hard winter.

The reasoning, such as it is, in many of these weather signs, is apparent on the surface. In the case of others it isn't, as with the most famous and well-known of them all—the groundhog sign. If Mister Woodchuck on Candelmas day—February 2—sees his shadow, issuing experimentally from his den, then "winter will have another flight." Otherwise an early spring impends.

Observation over a part of a single lifetime would demonstrate most of these weather signs as unreliable, yet they cling on, especially in country districts. It is possible that they do so, in part, because they shadow into animal signs of a different class which really are dependable. From the conduct of animals, accurate weather predictions can, within certain limits, be made.

This dependable class of animal weather signs is uniformly short distance as to prophecy—no longer than the daily newspaper weather forecast. They occur because

[1] "The Effects of the Freeze of Feb. 2–4, 1917, on the Insect Pests and Mites on Citrus," by W. W. Yothers, Bureau of Entomology, Orlando, Fla. From *The Florida Buggist*, vol. 1, No. 3, Dec. 21, 1917.

animals are more sensitive to atmospheric changes than human beings, and sense an approaching weather change hours before it is apparent to man. * * *

One animal barometer in this class, much observed east and west during the summer season, is the swallow. The swallow is insectivorous to the *-nth* degree. Other than insects hardly pass its bill from one season's end to another, and it captures this food on the wing. Thus it happens that as a weather forecaster the swallow on thousands of farms is always ready with an answer.

Swallows flying high indicate fair weather. Swallows flying low presage a storm. The explanation of these "signs" is simple. The relative level at which swallows fly is determined by the whereabouts of insects. The lighter [denser][1] the atmosphere, as in the case of fair weather or clearing weather, the higher will insects be found, while an oncoming storm, presaged by growing [decreasing][1] density, forces them to levels near the ground, where the swallows will be noticed in pursuit of them.

[1] Moist air is so frequently thought of as "heavy" that it is a common mistake to refer to it as dense, whereas moist air, volume for volume, is lighter than dry air. Furthermore, since clearing weather is almost invariably associated with falling temperature, decreasing humidity and rising pressure, all of which contribute to *increasing* density, and since the reverse is true with an on-coming storm, it is obvious that the effects described are associated with a tendency in density opposite to that mentioned.—EDITOR.

It has been observed by New Englanders that ants, sensing an approaching rain, will close the entrance to their small hills, and conversely, as weather clears, will open them. To this extent ants are found reliable forecasters. Instinctively they react to changes in the atmosphere and close their hills for protection against water.

A late fall and winter weather sign, which many country boys using box traps have learned the accuracy of, is furnished by the small coney rabbit, in rare cases by the more wary jack rabbit. These boy trappers note that catches of rabbits are always better just before a storm—the longer and more severe that storm proves, the more numerous the rabbits caught. Here again a change in the atmosphere has warned the rabbit tribe that a spell, during which food will be hard to obtain, is at hand and instinctively to "fill up," even to the point of entering traps they formerly had avoided. Country boys of New England know that if there is ever a time a rabbit will enter a box trap it is just before a snowstorm.

Doubtless other instances in which wild creatures function in the rôle of genuine weather forecasters could be advanced.

ABSTRACTS, REVIEWS, AND NOTES.

THE METEOROLOGICAL MAGAZINE.

[Reprinted from Nature, London, Mar. 18, 1920, p. 83.]

The "*Meteorological Magazine*," an official publication of the *Meteorological Office*, was first issued under its new title about the middle of February. The journal incorporates "Symons's *Meteorological Magazine*" and the "*Meteorological Office Circular*." For convenience in reference, the serial numbers of "*Symons's Meteorological Magazine*" are being carried on. The change has come about through the absorption of the British Rainfall Organization in the Meteorological Office. The cover of the new publication gives the portraits of four pioneers of meteorology, all of whom were associated with the Meteorological Office. Of these Admiral FitzRoy had charge of the Office at its initiation, when it was a branch of the Board of Trade, and Mr. Symons was an assistant 60 years ago, but left after a short period and devoted himself to the collection of rainfall returns, from which evolved later the British Rainfall Organization. Generals Sabine and Strachey were successively chairmen of the Meteorological Office when controlled by the Royal Society. Little change has been introduced into the style and character of the publication, and it is evidently not intended to make any radical alteration. In addition to the interesting article on "Weather in the British Isles" for the preceding month, which has hitherto regularly appeared in *Symons's Meteorological Magazine*, an article is now given on "Weather Abroad," which will doubtless be valued by readers of the journal.

METEOROLOGICAL MEETING AT VENICE.

An announcement has been received from the Italian Meteorological Society that the meeting originally called for September, 1914, but postponed on account of the war, will be held at Venice at a date in October to be announced in a later circular. The circular says, in part:

> The great problems presented by meteorological science having increased in number during the last few years, invite to a friendly meeting all the studious who, either as a duty or out of individual inclination, occupy themselves with meteorology.
>
> The exchange of opinions between colleagues [of different countries] who in these years have been obliged to suspend their studies or continue them amidst not inconsiderable fatigues, the renewed fellowship promise well for a profitable work, directed toward the sole aim of keeping high the flag of science, which is to a certain degree the object of our life.

METEOROLOGICAL STATIONS IN ECUADOR, 1920.

By FREDERIC W. GODING, Consul General.

[Guayaquil, Ecuador, Jan. 12, 1920.]

Recognizing the importance of forecasting weather conditions as practiced in many countries for the benefit of the agriculturist, the technical office of the Association of Agriculturists of Ecuador has inaugurated a similar system throughout the coastal provinces, including the Galapagos Islands. With that object in view 50 farms have been selected at convenient distances, where are being installed maximum and minimum thermometers and pluviometers, with which observations regarding the temperature and rainfall will be recorded daily, and published in a quarterly bulletin. At the end of each year averages of temperature and rainfall of the different sections will be established from these data, and, with the averages of various years, it will be possible to foretell approximately what the weather will be.

While at present it is not possible to foretell weather conditions very long in advance in any country, in the Tropics where climatic changes are usually sudden it will be specially true; yet, by comparing averages of several successive years, valuable advice can be given to those interested on the critical periods of each crop, thus permitting the farmer to calculate in advance the most favorable time to plant and harvest.

Meteorological stations thus far have been established at Baba, Barraganetal, Chobo, Rocafuerte, and Tonguel, to which 45 others are being selected.

IS VENUS CLOUD COVERED?

Mr. Evershed has taken many photographs of the spectrum of Venus in recent years for the purpose (inter alia) of endeavoring to detect the Einstein shift and of testing his own hypothesis that the earth has an effect on the atmospheric circulation of the sun. In the course of this work he found, to his surprise, that a much longer exposure time was needed than was the case in photographing the spectrum of a cumulus cloud on which the sun was shining (Monthly Notices R. A. S., November). Mr. Evershed expected the time to be shorter, for the intensity of sunlight on Venus is 1.92 times as great as on the earth. Allowing for the absorption of Venus's atmosphere, he concludes that if Venus were covered with clouds similar to our cumulus clouds the exposed time would be less on the former than on the latter in the ratio of 1 to 1.3, whereas the contrary is the case. He concludes that the atmosphere of Venus is not cloud laden, but that its lower strata contain much dust in suspension, veiling the surface features. This conclusion is similar to that reached by Prof. Lowell from his observations at Flagstaff.

Mr. Evershed thinks that the values of the color indices assigned by Prof. N. H. Russell to the sun and Venus (+0.79 m. and +0.78 m.) are mutually inconsistent, since they imply that no selective absorption takes place in Venus's atmosphere. Mr. Evershed finds evidence of decided selective absorption in the violet, as compared with his cloud spectra.—*Nature* (London), Feb. 19, 1920, p. 675.

REFERENCES TO LITERATURE ON ICE CAVES.

The explanation of the phenomena 'observed' in the ice cave at Coudersport, Pa. (*Scientific American*, May 6, 1919, pp. 470 and 495, reprinted in MONTHLY WEATHER REVIEW, Nov., 1919, pp. 803–804), is looked upon with some doubt, in view of the well-understood conditions in many such caves in various parts of the world. There is one proposition that indicates possible formation of ice in the summer time, namely, when air is so dry that the dewpoint is below the freezing point. This, however, is unlikely. In most cases heavy ice is formed late in winter and does not melt until far into the summer time. The following references supply much information on this subject:

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—*W. J. Humphreys.*

ROUND THE WORLD ON A VOYAGE OF 1,000 MILES.

After a voyage of 76 days from Melbourne, the barque *Inverneill* arrived at Bunbury, western Australia, on July 6 for Bunbury to load jarrah for South Africa, and soon after clearing Port Phillip Heads she struck a strong westerly gale, which continued for days. The vessel was driven out of her course, and through the straits. When on the other side of Wilsons Promontory the wind veered west, and the vessel was driven up the New South Wales coast. When the *Inverneill* was to the south of Sydney Heads the weather moderated, and so the captain decided to go on to Sydney.

After a short stay in Sydney he left again, and found the westerly winds still at their height. He then decided that instead of crossing the Bight he would go with the westerly wind around the world. Five days after setting sail he found himself at the north end of New Zealand, having gone a distance of approximately 1,200 nautical miles. This he considered a remarkably good record. As an average the barque traveled 240 miles a day. In 28 more days he was rounding the Horn with the wind still in a helpful direction. His trip continued for a further 33 days, when he found himself at St. Paul Island in the mid-Indian Ocean. From thence on to Bunbury the trip took 16 days. The trip was a fast one, owing to the steady westerly winds. Capt. Shippen himself estimated that the voyage would take approximately 95 days, whereas the trip from Sydney to Bunbury occupied but 76 days. Altogether Capt. Shippen estimates that he traveled 14,500 miles in his endeavor to go from Melbourne to Bunbury, and his average sailing time was 292 miles a day. He considers that such a passage has never been made before by a mariner, and expresses the opinion that he is doubtful if it will ever be repeated.—*Liverpool Journal of Commerce.*

THE WAVE-RAISING POWER OF NORTHWEST AND SOUTH WINDS COMPARED.

Mr. C. Kennedy, meteorological observer for the Weather Bureau on the British S. S. *Indian*, Capt. I. Chadwick, in a recent communication, asks the following interesting question:

> Why it is, that when we experience a wind from a northerly direction, especially northwesterly, the sea rises very quickly? On the contrary, if we experience a southerly wind, and if of a strong force, there is very little sea. This is in northern latitudes.

The following explanation of the point raised by Mr. Kennedy has been offered by Prof. W. J. Humphreys and Dr. C. F. Brooks of the Weather Bureau:

(1) Northwest winds usually are stronger than southerly winds over the America-to-England trade routes of the Atlantic and for this reason alone should give larger waves, since the wave effect increases at first much faster than the strength of the wind.

(2) Over much of this route the winds of winter (season of rough water) are prevailingly northwest. Hence, there usually are some waves of the northwest-wind type, due either to actual winds at the time and place, or to persistence of waves from more or less previous and distant storms. Any freshening of the northwest wind would then only increase the existing wave system. The crests of the existing waves would lie at right angles, roughly, to the new wind, and their sides would be exposed to its maximum pressure. On the other hand a wind from the south would, at first, meet with less surface obstruction (because blowing rather along the waves than against their sides) and thus be less efficient in raising a sea.

(3) A given wind has a greater wave-producing effect on an already rough sea than on a smooth one. Hence, as the ocean generally is rougher in winter than in summer, owing largely to the greater frequency and severity of storms during the cold season than during the warm one, it follows that a given winter wind (usually northwest) is likely to produce a higher sea than is an equal summer wind (usually

southerly). This prevailing greater roughness of the sea during winter than during summer gives the winds of the former season, the northwest winds, an advantage over those of the latter season, the southerly winds.

(4) The northwest winds usually have a downward component while the southern winds commonly have an upward component. The former are also more gusty than the latter, and for both reasons more disturbing to the water—more effective in starting waves.

(5) The winter northwest wind is denser, chiefly because colder, than is the southerly wind of any season, and thus through its greater momentum more likely to produce waves.

(6) Along most of the trade routes over the North Atlantic the course of the water, Gulf Stream and Drift, is from the south. Consequently the actual velocity of a given southerly wind with reference to the water, and hence its wave-producing effect, is less than that of an equal northerly wind.

There may be still other factors in favor of the northerly and northwesterly winds over the southerly winds as producers of waves, but the above are sufficient to confirm one's confidence in the observations to that effect.—*F. G. T.*

THE VARIABILITY OF CORRESPONDING SEASONS IN DIFFERENT YEARS.

By SIR FREDERICK STUPART, Director, Meteorological Office, Toronto.

[Abstracted from *Jour. Roy. Astron. Soc.* of Canada (Toronto), July–August, 1919, Vol XIII, pp. 259–263; reprinted in the *Scientific American Supplement*, New York, Sept 13, 1919, p. 163.]

A problem in meteorology which still remains unsolved is why corresponding seasons in different years differ so much in character. The author notes the following conditions which lead to the distinctive features of a climatic zone: (1) Distance from the Equator; (2) geographic position in relation to land and sea; (3) altitude; (4) the prevailing winds, the outcome of a general atmospheric circulation. Inasmuch as the first three factors are practically constants in any given case, the natural assumption is that the prime cause of seasonal climatic variation must be due to variation in atmospheric circulation. The writer then contrasts the remarkably cold winter of 1917–18 with the very mild winter of 1918–19, adding the pertinent question: "Why the difference?" He then proceeds to discuss what may be termed the *normal* distribution of atmospheric pressure and shows how the pressure of the two winters noted differ from the normal.

Referring to Canada and region to the northward, he says:

> In the early part of the winter of 1917–18 the anticyclonic type was more pronounced than in any other winter on record, and with most persistent areas of high barometer coming in over Yukon, perhaps indeed offshoots from the great Siberian winter anticyclone, the Northern Pacific low pressure was situated much farther south than usual and its offshoots, in the form of traveling low areas, passed into Canada over southern British Columbia and thence kept away to the southward, and the result was a prevalence of northerly winds, not only in the western Provinces but also in eastern Canada.
>
> During the winter just closed [1919] we find conditions in strong contrast to those of the previous year; the Northern Pacific LOW was extremely energetic and in a stream of offshoot cyclonic areas, which impinged on the northern Alaskan coast, prevented the formation of anticyclonic conditions, and, passing first southeastward, finally moved eastward as dispersing areas across the western Provinces, there giving most persistent gradients for southerly and southwesterly winds with unseasonably high temperature.

In closing, the author believes the time is now ripe for increased investigation regarding the changes, both in the position and the temperatures of the great ocean currents. "If it can be shown," he says, "that the great Japan Current in some years carries its warm waters farther north than in other years, it may not improbably be subsequently shown that in such years cyclonic conditions are more intense near the Alaskan coast, and we shall at once have valuable information regarding the probable distribution of barometric pressure in northwestern America, and this appears to be a dominating factor in the character of our winter seasons.

"While it would appear probable that conditions that would increase the temperature and the flow of ocean currents would act simultaneously in both hemispheres, it does not necessarily follow that the effect on the northern coast of Europe would occur simultaneously with the effect on the northwest coast of America. One would surmise that as the source of the Gulf Stream is nearer the British Isles than is the source of the Japan Current to Alaska, therefore Europe would be affected before America and quite possibly this is the case. The whole question is complex but well worthy of study."—*H. Lyman.*

WINTERS AT NEW YORK CITY.

By J. MALCOLM BIRD.

[Notes on article "What about the old-fashioned winter?" *Scientific American*, Mar. 6, 1920, pp. 253, 261, 262, 3 figs.]

Graphs of winter snowfall, of winter average temperature, and of dates of opening and closing of navigation on rivers, for a long period, are always interesting to study, especially, since the results of such investigation recalls past snowy or cold winters and show that unusual winters are not of infrequent occurrence. The extraordinarily cold winter of 1917–18 does not stand as a marked anomaly on the temperature graph for New York City for the last 50 years, nor (except on the snowfall graph) does the mild winter of 1918–19 look so striking as it seemed. The past winter as shown by the graphs for New York City was an ordinary one.

The graph showing the duration of closed navigation on the Hudson between New York and Albany for the last 75 years is of considerable interest. The average duration of closed navigation is 101 days, from December 14 to March 25. The extremes were 140 days in 1896–97, and 0 days 1912–13, November 22 (1873), and April 29 (1897).

DISCUSSION.

The winter of 1896–97 having the longest duration of closed navigation was only a fraction of a degree below normal in temperature and had only 4 inches more than the average snowfall. This should be a caution to those who seek from ice-in-rivers statistics to draw conclusions as to the characters of winters.

The graph of winter snowfall shows a general decrease in the depth of snowfall during the last 30 years. The maximum of 76 inches in 1892–93 has been followed by snowy winters having 58 (1898–99), 57 (1904–5), 52 (1906–7), 47 (1915–16), 49 (1916–17), and 46 (1919–20). The successive minima (below 25 inches) have been 25 (1885–86), 22 (1888–89), 20 (1897–98), 20 (1899–1900), 10 (1900–1901), 23 (1905–6), 21 (1908–9), 16 (1912–13), and 4 (1918–19). Perhaps the growth of the city and the consequent increase of its effective heating of the air under the low clouds when snow is falling is responsible for this apparent decrease in snowiness. The temperature records do not give any indication of a tendency to warmer winters. In the coldest weather, when much snow is not likely to fall, the sky is usually clear and the wind strong enough to allow heating of the air by the city to have no appreciable effect on the temperature. On warm days the artificial heating of buildings is negli-

gible, and the heat from the combustion of fuel for power and light is likely to be distributed through a considerable layer of air by convection. Thus even though it may affect the depth of snowfall, the city heat has small effects either in ameliorating the coldest weather or in making the hottest weather worse.

A final point may be worth mentioning. The graph of the mean temperatures of winters during the past 50 years shows that each of six of the seven which were more than 3° F. below normal at New York City, was followed by a winter having a temperature above normal and at least 4° above that of the cold winter. The winter just past has been the eighth cold one. Are the chances 6 to 1 that next winter will be warmer than normal?—*Charles F. Brooks.*

ON THE INFLUENCE OF LARGE CITIES ON CLIMATE.

[From abstract in *Prometheus*, Apr. 6, 1918, p. 259.]

It is believed that large cities may effect climate through the following means: (1) Discharging into the air soot, dust, and gases; (2) the rapid removal of precipitation, which would decrease the effects of evaporations; and, (3) increasing of temperature. Wilhelm Schmidt has investigated the warming effect of Vienna, and finds, through a knowledge of the amount of various kinds of fuel used in 1913, that the total heat obtained from burning fuel was 5.3×10^{12} kg. calories. In addition, there is the contribution of animal heat, and he finds that the population of Vienna, 2,130,000, set free 1.56×10^{12} kg. calories in the year. 35,000 horses and 9,500 head of cattle contributed 0.16×10^{12} kg. calories. This gives a total of about 7 billion kilogram-calories for the year, which, compared with the heat received from the sun, amounts to about one-sixth for the area of the city.

For more closely built cities such as Berlin, this value is increased, amounting for Berlin and Potsdam to one-third the heat received from the sun.—*C. L. M.*

WINTER TYPES ON THE BASIS OF FIVE-DAY TEMPERATURE MEANS.

By FRIEDRICH KLENGEL.

[Abstracted from *Meteorologische Zeitschrift*, March–April, 1918, pp. 65–74.]

By analyzing the temperature records of 30 years at Plauen, the author shows how the use of monthly means may give an erroneous impression of the type of winter. Diagrams showing the monthly means during the months November to March, inclusive, and showing the pentad [1] means for several individual winters are compared, and it is found that those winters which stand out as extreme are those which have one or more long periods of extremely cold weather. The winter in which there are alternating periods of cold and warm weather does not give the general impression of a cold one, even though the minima be equally low. The pentad curves show these fluctuations, whereas the monthly means will not. The winter of 1917–18 illustrates this: it was considered the most severe since the winter of 1870–71, but the mean temperature stood seventh in the list of coldest winters.—*C. L. M.*

[1] Attention is invited to Prof. C. F. Marvin's discussion of the week as a convenient subunit for the discussion of annual meteorological data: MONTHLY WEATHER REVIEW, August, 1919, 47: 546.—EDITOR.

ON MILD WINTERS.[1]

By G. HELLMANN.

[Reprinted from *Science Abstracts*, July, 1918, p. 286–287, § 739.]

A measure of the degree of mildness of a winter is obtained by forming the sum of the positive daily means (in degrees centigrade) of temperature from December 1 to the last day of February. [Severe winters were dealt with similarly by taking the negative daily means, see Abs. 624 (1918).] These sums vary in Berlin, in 150 years, 1766 to 1916, between 412 and 22, the mean value being 171. Mild winters are more frequent than severe ones and have a less decided character. In some "mild" winters occur comparatively brief periods of severe frost. The mildest winter experienced in Berlin was that of 1795–96, the mild period of which lasted from December 2 to February 26. No snow fell between November 29 and February 10, a fact which was "without parallel since 1701." Trees burst into leaf at the end of January. The longest mild winters were those of 1821–22 and 1823–24, which lasted from about November 10 to the end of March in both cases.

The following general conclusions are set out: Very mild winters usually commence in November and last till March. The highest temperatures occur most frequently in December and least frequently in January. The highest temperatures to be expected are 14° to 15° C. (In severe winters the lowest temperatures are about —28° C.) Characteristics of very mild winters are much cloud, high humidity and rainfall, unsettled weather with much wind. Occasionally mild winters are, however, characterized by quiet, foggy weather, with much cloud and little rain. In mild winters the wind generally comes from the west. There is no regularity in the occurrence of mild winters, but they have been much more frequent in Berlin since 1862 than before. In the period 1909–10 to 1915–16, there were 7 winters, of which 5 were very mild and 1 was mild. Hence the comparatively severe winter of 1916–17 was the more remarked upon. After very mild winters there is usually a cold snap in March or April, and a normal or warm summer.—*R. C.*

LONG-RANGE FORECASTS OF JAPAN'S RICE CROP.[2]

By T. OKADA.

[Reprinted from *Nature*, London, Jan. 15, 1920, p. 509.]

In the Bulletin of the Central Meteorological Observatory of Japan (vol. iii, No. 1) Prof. T. Okada attempts to discover a forecasting formula, starting from the undoubted fact that in Japan a hot August means a good crop, and a cold August a bad one, resulting in famine in 1902, 1905, and 1913. Prof. Okada connects the temperature of northern Japan with the sun-spot cycle, but more definitely finds a correlation between the August temperature in that region, the March pressure difference between Zikawei and Miyazaki, and the South American pressure for March to May, using data from Santiago and Buenos Aires. The South American data give larger correlation coefficients (0.5 or 0.6 with P. E. <0.1) than the Zikawei-Miyazaki pressure differences (0.3 or 0.4 with P. E. >0.1). Treating the districts of Hokkaido and Tohoku separately, he obtains the yearly variation in the rice crop for the former as $0.53x+0.26y$, and for the lat-

[1] Preuss. Akad. Wiss. Berlin, Ber. 11, pp. 213–220, 1918.
[2] Bull. of the Central Meteorological Observatory of Japan, vol. 3, No. 1, 1919.

ter as $0.18x+0.10y$, where x is the yearly variation of South American pressure, March to May, and y the yearly variation of pressure gradient, Zikawei-Miyazaki. The table of comparative results shows a fair agreement in sign between calculated and actual yields, especially for Hokkaido, and the conclusion is drawn that, in general, abnormally low pressure in the southern part of South America from March to May and abnormally small pressure gradient in March between Zikawei and Miyazaki are followed by a failure of the rice crop in northern Japan.

RADIO AMATEURS GET WEATHER REPORTS.

An amateur radio operator in North Dakota has written the Weather Bureau, United States Department of Agriculture, that he is daily receiving the weather forecasts sent out by the powerful wireless station at Arlington, Va. In Kansas, according to reports, the State agricultural college is now sending out weather reports by wireless every morning except Sunday, for the benefit of a considerable number of amateurs, many of whom live in the rural districts of that State and so are able to be of service to the farmers in their neighborhoods. No doubt in other parts of the country there are those who are "listening in" on the dispatches sent out by high-powered radio towers.

The sending of the Weather Bureau's forecasts by radio is in charge of the Navy, hence at many points far inland it is improbable that amateurs could pick up the messages. The Weather Bureau has carefully considered the possibilities of further use of the wireless in inland districts, but owing to an arrangement made some years ago whereby the bureau relinquished radio activity in favor of the Army for inland communication and the Navy for coastal work it has not been feasible to extend the forecast service in this manner. However, what the amateur in North Dakota and those in Kansas have been able to do suggests that others might "pick up" the weather reports, thereby securing them considerably in advance of the published reports.—*Weekly News Letter*, U. S. Dept. Agric., Mar. 31, 1920, p. 7.

American stations issuing daily meteorological bulletins are: Arlington, Va. (2,500); Key West, Fla. (2,400); Great Lakes Training Station, Ill. (1,512); North Head, Wash. (600); San Francisco, Calif. (600); and San Diego, Calif. (600). The time of all messages is 10 p. m., 75th meridian time and the wave lengths in meters are given in parentheses for each station.

INTERNATIONAL METEOROLOGICAL RADIO-SENDING STATIONS.

The Supplement to *La Nature* of January 10, 1920, page 9, contains a list of European wireless stations, which have in their daily program certain times for sending meteorological information.

Station.	Wave length (meters).	Time (G. M. T.)
Whitehall, Orkney Islands	2,800	9:30 20:30
Paris, France	2,600	9:45 16:00 21:30
Cleethropes, England	3,000	10:00 22:00
Scheveningen, Netherlands	1,800	11:15
Madrid, Spain	2,000	13:29

It is noted that the times of these messages are subject to change.—*C. L. M.*

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C. F. TALMAN, Professor in Charge of Library.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING FEBRUARY, 1920.

By H. H. KIMBALL.

[Pending a decision as to an appropriate reduced form in which to present these data, publication will be delayed.]

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, JANUARY, 1920.

By C. G. ABBOT, Director.

[Astrophysical Observatory, Smithsonian Institution, Washington, Mar. 30, 1920.]

In continuation of preceding publications I give in the following table the results obtained at Calama, Chile, in January, 1920, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

The high values which prevailed during the latter half of October and the months of November and December have continued through January; indeed have reached almost unprecedentedly high values. The observers report exceptional cloudiness, so that if it were not for the new method they would not have been able to observe more than two or three times during the month. The three observations which they did make by the older method agree quite as closely as could be expected with those by the new, so that it seems justified to believe that the extraordinarily high values correspond to real conditions on the sun. Readers may recall that a secondary correction for humidity is employed at Mount Wilson, but not at Calama. It is not surprising, therefore, that on such very humid days as January 19 and January 25 values by the old method should have fallen as much as 1 per cent below those by the new.

In view of this paradoxical phenomenon of high solar radiation and uncommonly low temperatures in the United States, with exceptional cloudiness and precipitation here and elsewhere, attention is drawn to the well-verified fact that the temperatures are lower during periods of sun-spot maximum than at times of sun-spot minimum. The mean values of solar radiation, however, were several per cent higher in the periods of many sun spots, 1905 to 1909 and 1914 to 1919, than they were in the period of few sun spots, 1910 to 1913. It may be supposed that attending great solar activity conditions are favorable for exceptional cloudiness, and this, by reflecting away the solar radiation, diminishes the amount available to warm the earth, so that the high solar radiation and low terrestrial temperature may therefore be rendered consistent with each other. Another hypothesis may be that increased solar radiation alters the positions of the great action centers in the atmosphere so that prevailingly polar winds are substituted for prevailingly equatorial winds attending high values of the solar radiation.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. ρ/ρ s.c.	Humidity. V. P.	Humidity. Relative humidity.	Remarks.
1920. A. M.	*Cal.*			0.853	0.454	*Cm.* 0.51	% 48	
Jan. 2	1.971	E_0	E—					Distant cirri in east and north.
	1.974	M_2						
	1.973	M_2						
	1.959	$M_{1.5}$						
	1.970	W. M.						
3	1.985	M_2	S—	.842	.485	.46	32	Cirri in distant east and north.
	1.967	$M_{1.5}$						
	1.976	W. M.						
4	1.969	M_2	S	.848	.526	.44	32	Cirri in north and east below sun.
	1.959	$M_{1.5}$						
	1.964	W. M.						
5	1.964	$M_{1.22}$	S—	.848	.593	.47	31	Cirri over most of sky, but clear space around sun.
P. M.								
Jan. 7	1.977	$M_{2.13}$	U+	.828	.338	.51	23	Cirro-cumuli in east. Very thin cirri over much of west.
A. M.								
Jan. 10	2.027	M_2	U+	.829	.319	.44	31	Thin cirri scattered around much of sky.
11	1.979	$M_{1.29}$	U+	.819	.368	.58	39	Scattered cirri preventing earlier observations.
12	1.955	$M_{1.62}$	S—	.822	.425	.90	51	Scattered cirri in east. Cumuli all around horizon, especially in east.
	1.955	$M_{1.01}$						
	1.955	W_1 M.						
14	1.962	M^1	U+	.844	.527	.75	42	Thin cirri scattered about sky.
15	2.016	M_2	U+	.814	.330	.59	44	Cirri scattered around horizon.
	1.992	$M_{1.5}$						
	2.000	W. M.						
17	2.030	M_2	U+	.813	.308	.79	56	Some thin cirri around horizon and few cumuli in east.
	1.983	$M_{1.5}$						
	1.995	W. M.						
18	1.996	M_2	U+	.817	.319	.84	54	Some cirri low in east. Small cumuli in north and south.
	1.971	$M_{1.5}$						
	1.981	W. M.						
19	1.956	E_0	G	.834	.251	.75	61	Some cirri in north.
	2.053	M_2						
	2.011	M_2						
	1.976	$M_{1.5}$						
	1.989	W. M.						
20	1.947	$M_{1.5}$	U+	.816	.350	.75	50	Cirri around sun, but disappearing. Cumuli in north.
21	1.971	M_2	U	.813	.302	.75	53	Cirri in east, north, and south.
	1.921	$M_{1.39}$						
	1.954	W. M.						
22	1.973	$M_{1.12}$	U+	.829	.412	.89	56	Cirro-cumuli scattered about sky.
23	2.006	M_2	S	.834	.330	.71	47	Cumuli low in east and cirro-cumuli in northwest.
	1.997	$M_{1.56}$						
	2.001	W. M.						
24	2.006	M_2	S—	.826	.319	.71	50	Cirro-cumuli over most of sky.
	1.981	$M_{1.5}$						
	1.998	W. M.						
25	1.957	E_0	VG—	.838	.275	.67	57	Some cirro-cumuli low in east.
	2.008	M_2						
	1.979	M_2						
	1.969	$M_{1.9}$						
	1.978	W. M.						
26	1.958	$M_{1.08}$	S—	.837	.464	.75	44	Cirri scattered about sky.
27	1.977	M_2	S	.835	.318	.66	37	Few cumuli at eastern horizon.
	1.971	$M_{1.5}$						
	1.975	W. M.						
28	1.977	M_2	S	.837	.331	.52	32	Cirri in west and south. Cumuli forming at horizon in east.
	1.964	$M_{1.5}$						
	1.973	W. M.						
29	1.963	$M_{1.13}$	U+	.817	.410	.88	50	Cirri scattered about sky.
30	1.976	$M_{1.23}$	S—	.825	.376	.73	46	Cirri scattered over much of sky.
31	1.983	M_2	S—	.820	.303	.83	63	Scattered cumuli around north. Cirri and cumuli in south.
	1.952	$M_{1.5}$						
	1.975	W. M.						

THE RELATION BETWEEN SIMULTANEOUS VARIATIONS OF PRESSURE AND SOLAR ACTIVITY.[1]

By S. HANZLIK.

[Reprinted from *Science Abstracts*, Sect. A., July, 1918, p. 287.]

At times of sun-spot minima the conditions of pressure over the west coasts of the European and North American Continents are such that high pressure in the western United States corresponds with low pressure in western Europe, and vice versa. At times of sun-spot maxima the reverse is the case; that is, weather conditions in the two regions are similar, fine weather being experienced simultaneously and stormy weather likewise occurring at the same time in both places.—*R. C.*

[1] Akad. Wiss. Wien, Ber. 126, 3pp., 371-386. 1917.

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By ALFRED J. HENRY, Meteorologist.

Pressure at the two Pacific stations, Midway and Honolulu, also in the Aleutian regions and at Nome, Alaska, was for the most part below normal. On the south coast of Alaska and to a less extent in the interior, pressure was above normal practically the entire month after about the 7th. Such a pressure distribution would seem to indicate that cyclonic depressions which normally develop in the Gulf of Alaska and move thence to the southeast moved to the northeast as disturbancies of little intensity.

The outstanding feature of cyclonic distribution in the United States was the failure of such storms to move inland from the Pacific and thence southeastward over the Plateau and Rocky Mountain regions. Coupled with that failure, however, there was a marked tendency toward the development of intense cyclones over northeastern United States.

In general, the weather in the United States and Canada was appropriate to a winter month except that in two widely separate regions extreme conditions prevailed, a result directly traceable to the movement of cyclones as indicated in the previous paragraph. In Pacific Coast States there was an absence of precipitation which may seriously affect economic conditions in those States should the shortage of precipitation continue during March. In northeastern Atlantic Coast States, including the Canadian Maritime Provinces and eastern Quebec, stormy weather with heavy snow prevailed during almost 50 per cent of the time. In New England and New York heavy snow seriously interfered with transportation problems, and the month may be classed as of the "old fashioned winter" type.[1]

While there were no wide-spread and severe cold waves, freezing temperatures overspread Southeastern States, including Florida, toward the end of the month. The month as a whole was relatively cold east of the Mississippi and warm west of it.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The month opened with a pronounced fall in pressure over the region adjacent to the Aleutian Islands where previously, during the middle and last decades of January, it had been abnormally high. During the entire month there was rather marked atmospheric activity over the Pacific as compared with the preceding months of December and January, in which conditions were unusually quiet for the winter season.

The depression which overspread the region between the Aleutians and Hawaiian Islands during the early days of the month caused strong westerly winds and gales over the northern steamer routes from midocean westward to the Japanese Islands.

Mr. C. R. Jowsey, second officer of the British S. S. *Tahchee*, Capt. D. M. Mackenzie, from San Pedro for Yokohama, states that from longitude 141° W., to the Japanese coast there was a continuation of westerly winds from force 6 to 10, with fierce squalls after passing the 180th meridian. Short intervals of light airs and calms, from 4 to 8 hours in duration, were experienced between blows, with bright, clear weather throughout day and night, except on approaching the coast, when cloudy and squally weather prevailed.

The principal disturbance of the month appears to have been that of the 9th–13th. Between those dates vessels near the 180th meridian experienced winds reaching the force of a whole gale. Mr. I. N. Barr, observer on the British S. S. *Ixion*, Capt. J. Inkster, from Yokohama for Victoria, states that at 2 a. m. on the 11th, after a vivid display of lightning in various quarters, a sudden gale from the northwest struck the ship. The wind attained its greatest violence about noon of the 12th, the vessel then being hove to in latitude 38° 28′ N., longitude 151° 21′ E. The gale was accompanied by terrific squalls and a very high sea, while a high swell from the northeast was continually running. Similar conditions were experienced on the 18th, when the *Ixion* was in latitude 49° 01′ N., longitude 176° 17′ W.

It is interesting to note that while there was greater atmospheric activity over the North Pacific Ocean in February than in either December or January the reverse was true of the North Atlantic Ocean, where, after two months of stormy weather, conditions moderated somewhat, as appears from the accompanying review of conditions over that ocean.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was slightly above the normal at land stations on the coasts of Newfoundland and Canada, while it was somewhat lower than usual on the coast of the United States and also in the West Indies and the Bermudas. In the neighborhood of the Orkney Islands the pressure was practically normal, while on the south coast of Ireland, in the English Channel, and in the Azores it was considerably above.

According to reports received, the num er of days on which gales were observed over the steamer lanes was slightly less than usual, as they were not reported on more than five days in any one 5-degree square. In the square that includes Bermuda they occurred on four days, which is slightly above the normal for that locality.

Fog was apparently less prevalent than usual during the month over the entire ocean, and it was reported on only three days on the Banks of Newfoundland and adjoining region.

On February 1 and 2 moderate to strong southerly and southwesterly gales prevailed over the middle and eastern sections of the steamer lanes. On the former date the pressure was abnormally high on the American coast north of New York, as a number of stations reported barometric readings of 31 inches or over. On the 3d and 4th heavy weather continued in mid-ocean, and on the 4th two vessels between the 35th and 46th parallels and the 68th meridian and the American coast encountered strong easterly gales accompanied by high barometric

[1] See p. 78 above.

readings at the time of observation. The storm log from the American S. S. *West Alsek* is as follows: "Gale began on the 4th. Lowest barometer, 29.70 inches on the 5th. Position, 40° 20′ N., 71° 00′ W. End of gale on the 6th. Highest force, 10. Shifts of wind near time of lowest barometer, east to southeast."

The conditions on the 5th, 6th, and 7th are shown on Charts IX, X, and XI, respectively, and it will be noted that on the last two days unusually heavy winds prevailed in the vicinity of the Bermudas, with a well-developed LOW over the New England and Canadian coasts. On the 8th and 9th a number of vessels in mid-ocean encountered southwesterly gales, with a low central somewhere in the region between Scotland and Iceland, and an unusually steep gradient toward the south. The storm log from the Danish S. S. *Oscar II* is as follows: "Gale began on the 5th. Lowest barometer reading, 29.22 inches at 6 a. m. on the 7th. Position, 56° 20′ N., 22° 48′ W. End of gale at 8 a. m. on the 9th. Highest force of wind, 9. Shifts of wind, south to northwest through the east."

On the 11th moderate to strong westerly gales prevailed over a limited area between the 40th and 45th parallels and the 40th and 50th meridians, and at the same time there was a deep depression over the Scandinavian coast. On the 12th and 13th the conditions were comparatively featureless, with slight pressure gradients and light to moderate winds over nearly all the ocean, although on the latter date the station at Bermuda reported a southerly gale of about 50 miles an hour. On the 15th, as shown on Chart XII, there were three well-developed LOWS over the ocean, with gales prevailing over the greater part of the steamer lanes east of the 50th meridian. During the next two days all three disturbances decreased somewhat in intensity, although on both the 16th and 17th southerly gales were encountered over the northeastern section of the ocean, and on the 16th southwesterly winds of gale force occurred off the New England coast. On the 19th there was a LOW central about 200 miles east of the Virginia Capes, and heavy northwesterly winds were reported in the southwesterly quadrants. From the 20th to the 25th light to moderate winds prevailed over practically the entire ocean, although during that period a few vessels in widely scattered localities reported moderate gales.

On the 26th (see Chart XIII) a well-developed LOW was central near the west coast of Newfoundland, while southerly and southwesterly gales swept the steamer lanes west of the 40th meridian. As shown on Chart XIV, this disturbance moved but little during the next 24 hours, decreasing in intensity, and by the 27th the storm area had contracted considerably in extent. The conditions on the 28th were practically the same as on the previous day, while on the 29th the LOW had apparently filled in, light to moderate winds being the rule over the greater part of the ocean. The Danish S. S. *Oscar II* reported a westerly gale of over 60 miles an hour while near latitude 56° and longitude 24° on the 29th, and the storm log from this vessel is as follows: "Gale began on the 26th. Lowest barometer, 29.25 inches at 4 a. m. on the 29th. Position, 53° 30′ N., 27° 30′ W. End of gale on the 29th. Highest force of wind, 10. Shifts of wind, southeast to west-southwest."

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Nova Scotia.—Sydney, February 23.—Supplies for the inhabitants of the Magdalen Islands, icebound and on limited rations for several weeks, have been landed on Grindstone Island, one of the group, according to a wireless message received here from the government steamer *Montcalm.*—*Washington Star.*

Halifax, February 18.—Arctic ice packs, covered with walrus, seals, and other polar creatures, are the largest within memory, according to reports brought here by sailors and overland travelers.

The solid ice extends farther south than at any time within years, with the bays and inlets fringing the Newfoundland coast, locked tightly. Newfoundland railroads are completely tied up and inhabitants in the interior are suffering intensely. Communication between settlements is impossible except by dog sleds.

Reports of a strange malady have been received from Gander Bay, which is without a physician. The disease is an affection of the throat and has claimed many lives.—*New York Times, February 19, 1920.*

British Isles.—February was characterized by a mean temperature decidedly in excess of the normal, a moderate amount of sunshine, and an absence of the boisterous conditions which prevailed in January. * * * The general rainfall expressed as a percentage of the average was: England and Wales, 77; Scotland, 164; Ireland, 89; British Isles, 112.

In London (Camden Square) the mean temperature was 43°, or 3.3° above the average, it being the third successive month with an excess of more than 3° F.[1]

France.—In western Europe the rainy and stormy weather of January continued during the month, though with less severity. The heaviest rains occurred in association with a depression which passed from Portugal to the Mediterranean. At Perpignan, on the north side of its path, 25 mm. and 48 mm. of rain were measured for consecutive days, the 19th and 20th. Floods were subsequently reported at many places in the south of France. High temperatures occurred on the Continent, as in the British Isles, on the 17th, when the maximum at Strasbourg was as high as 69° F.[1]

Madeira.—Phenomenal rain fell at Madeira on the 25th and 26th, the total fall of 48 hours being 213 mm., or 8.5 inches.[1]

Turkey.—Constantinople, February 24.—A heavy snowstorm has been beating down on us for the last three or four days without ceasing; the streets are knee deep in soft snow, and since most of the houses have few facilities for heating and less fuel to make use of these with, we are all cold and shivering and miserable.—*New York Evening Post, March 27, 1920.*

Palestine.—The worst winter ever recorded is being experienced in the Holy Land and the whole region to the east of the Mediterranean. In Jerusalem there was a fall of 39 inches of snow [the greatest since 1860].[1] Great distress was caused, as the people are not prepared to resist such weather. Communication between Jerusalem and Cairo was interrupted for a week.

During the recent storms the historic tree in the Garden of Gethsemane known to the Arabs as "El Bustini" was blown down. According to local tradition the fall of this tree would presage the fall of the Turkish empire. The Turks, in order to head off such a bad sign had kept the tree bound up with iron braces, but the heavy snowfall was too much for the old tree and it was prostrated. Now the word is spreading among all the people that the long-predicted end of Turkish rule is close at hand.—*The Pathfinder, Washington, March 6, 1920.*

[1] The Metereological Magazine (London), March, 1920, pp. 31 and 36.

For several days the city was cut off from outside communication. Telegraph and telephone wires fell and railroad traffic was paralyzed, which produced an acute shortage of food. Hundreds of persons were made homeless when the roofs of their dwellings gave way beneath the weight of the snow, while other buildings fell when their foundations were undermined by the melting snow. * * *

Eight hundred homeless persons are being housed in synagogues and school rooms until new homes can be provided for them. * * * it will be months before all the damage can be repaired.—*New York Evening Mail, March 30, 1920.* (See also p. 80 above.)

Australia.—In Australia the welcome rains continued.[1]

South Africa.—The serious drought which (has) been prevalent in South Africa was broken by copious (rain) falls.[1]

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By R. HANSON WEIGHTMAN, Meteorologist.

Cyclones.—The month was marked by the occurrence of 9 secondary developments, while the number of primary lows amounted to 11. Disturbances were more than usually numerous in southern districts (see Chart II). The table below gives the number of lows by types:

	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
February, 1920..	6.0	0.0	2.0	2.0	2.0	1.0	1.0	3.0	3.0	20.0
Average number, 1892–1912.....	3.1	2.3	1.0	0.2	1.5	1.5	0.5	0.2	0.7	11.9

Anticyclones.—The number of highs as shown on Chart III was greater than the average as shown in the table giving the types and number of each which follows:

	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
February 1920.....	0.0	1.0	7.0	2.0	0.0	10.0
Average number, 1892–1912.....	0.8	0.5	4.7	1.2	0.6	7.8

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Apr. 1, 1920.]

PRESSURE AND WINDS.

The abnormally high pressure over eastern districts at the close of January was central over New England and the Canadian Maritime Provinces by the morning of February 1, with pressure still above 31 inches, some stations reporting the highest barometer readings ever observed. Temperatures also were extremely low, falling to nearly 50° below zero (F.), in northern New England. This high area moved rapidly into the Atlantic, and was quickly followed by another that prevailed for several days over the northern districts from the Great Lakes eastward. During the same period, pressure was generally high over the far West and low in the Southeast, where a shallow depression, developing over southern Florida at the beginning of the month, moved northward and by the morning of the 5th was central off the middle Atlantic coast as a severe storm. It moved slowly to southeastern New England during the following 24 hours, attended by strong winds and high tides that caused much damage to the cities and towns along the coast from Virginia northward. At points along the coast, the storm is described as being the severest ever experienced. Inland, heavy sleet and snow prevailed almost continuously for several days, accumulating to unusual depths from the Chesapeake Bay region northward, but particularly over southeastern New York and New England, where, on account of drifting and freezing, railway and other transportation interests were paralyzed, mail routes were abandoned, and business was generally demoralized.

Throughout the balance of the first decade pressure remained above normal in the far West, and in fact continued so throughout the greater part of the month. No important storm entered the country from the Pacific or from the Canadian northwest, during the second or third decades of the month, but several storms originating in the central or southern districts increased markedly in their eastward progress and on reaching the middle Atlantic coast had attained considerable proportions, frequently becoming severe over the more northern districts.

The average pressure for the month was above normal over practically all portions of the United States and Canada, from the Mississippi River and Great Lakes westward to the Pacific, the departure increasing in the far northwestern districts, where at points the average pressure for the month was the highest of record. In the eastern districts of the United States, as well as Canada, the pressure for the month as a whole averaged considerably less than normal, particularly along the middle Atlantic coast, where the barometer readings were decidedly low on several occasions.

The high pressure existing from the Missouri Valley westward to the Pacific, during the greater part of the month with its center over the far northwestern States, and the generally low pressure over the more eastern and southern districts, greatly influenced the course of the winds from the Rocky Mountains eastward where they were nearly everywhere from the Northwest. To the westward of the mountains, the winds were greatly diversified but also frequently from the northwest. High winds were observed on a number of dates along the Atlantic coast, particularly on the 4th and 5th, and again about the 14th and 15th. Over the remaining portions of the country, winds of 50 miles per hour or over were reported at a few points only, and along the Pacific coast where high winds are usually frequent during February, they were notably absent.

TEMPERATURE.

Severe cold, extending over from January, prevailed on the first of the month over the eastern districts from Pennsylvania northward, where the lowest temperatures

[1] The Meteorological Magazine, March, 1920, p. 36.

of the month were recorded, the minimum readings ranging frequently from 30° to nearly 50° below zero (F.), at exposed points in the northern portions of New York and New England. As this cold area moved beyond the field of observation, warmer weather prevailed in the districts from the Mississippi Valley eastward, some of the highest temperatures of the month occurring on the 2d and 3d in the Ohio Valley and Great Lakes region and to the eastward, and generally moderate temperatures prevailed in the far West, particularly in California and Arizona, where the highest temperatures of the month were also frequently reported. Cold weather again set in over the Dakotas about the 3d, and gradually extended to the Great Lakes and New England during the following two days, but elsewhere temperatures remained moderate for the season. No important temperature changes were recorded during the latter part of the first decade or in the early period of the second. On the 13th low temperatures again entered the upper Missouri Valley and gradually overspread the northern and central districts during the middle portion of the second decade, the minimum temperatures falling to 30° or 40° below zero (F.), over the northern States from the Rocky Mountains to the Great Lakes, and they were below zero at exposed points as far south as Oklahoma and thence eastward to the mountains of North Carolina. This period brought the coldest weather of the month over most of the country between the Rocky and the Appalachian Mountains, and killing frosts occurred near the Gulf coast and over northern Florida. The latter part of the second decade had mainly moderate temperatures over all districts.

The early part of the last decade had moderately low temperatures in the Northwest, and it continued cold over portions of the Northeast where the heavy body of snow prevented any material warming. In most of the mountain districts of the West the lowest temperatures occurred during this decade, principally about the middle and near the end, the minimum temperatures falling to nearly 40° below zero at exposed points in Wyoming, and ranging from 20° to 30° below zero in portions of Utah and Idaho. Over the interior districts the temperature during the last decade was without sharp changes and remained very generally above the normal.

For the month as a whole the average temperature was above the normal in practically all portions of the country to westward of the Mississippi River, the average daily excess ranging from 6° to 9° in the Dakotas and portions of surrounding States; and the excess was only slightly less in portions of the Plateau region. East of the Mississippi River the averages were everywhere less than normal, though usually the departures were not large. In the northeastern districts, particularly over New York and New England, the month was largely cold throughout, and while extremely low temperatures were not observed, the continued cold prevented any material melting of the heavy snows, and at the end of the month the accumulated snow of nearly the entire winter remained on the ground, and in some sections the depth was the greatest in many years.

The extremes of temperature were within the usual limits, although the minima of the first over portions of New England were close to the lowest ever observed. The maximum temperatures were usually above 80° over the southern tier of States, reaching 93° at points in Texas. In the Lake Superior district they were not much above 40°. The minimum readings by States ranged from 19° in Florida and 21° in Louisiana to −45° in New Hampshire.

PRECIPITATION.

The month as a whole was abnormally dry over large portions of the country, particularly in the central valleys and the far West. On the other hand, precipitation was frequent in the Atlantic Coast States, particularly from Virginia northward, where heavy snows, rains, and sleet were of frequent occurrence, and the monthly amounts were generally above normal. There was an excess of precipitation over most of Florida and the States of the far Southwest had monthly amounts in excess of the average.

The most notable storm of the month had its origin over extreme southern Florida at the beginning of the month. By the morning of the 4th it had moved to the Carolina coast, attended by heavy rains over the southeastern States, nearly 7 inches falling at Jacksonville from the 1st to the 3d. This storm moved slowly northward along the coast during the following few days, the heavy rains changing to heavy sleet as the storm moved into northern and cooler regions, and to heavy snow over the western and northern areas embraced within the storm's influence. The fall of sleet in this storm was remarkably heavy and continued over a period of unusual length; in some cases the fall continued without material interruption for two days or more.

A second period of important precipitation prevailed over the southern and eastern districts from the 12th to 15th, during which time considerable snow occurred over the northeastern States and some heavy rains fell in the Gulf States and along the Atlantic coast as far north as Chesapeake Bay. The latter half of the month was markedly free from material precipitation over southern and western districts, and in many parts of the Northwest the month as a whole had the least precipitation of record for a winter month. In portions of Oregon and Washington the precipitation was less than 10 per cent of the normal. This condition prevailed even to the coast stations, where February is usually a distinctly rainy month. At Tatoosh Island, off the northwest coast of Washington, no precipitation of any kind was observed from the 7th to the 29th, inclusive, the longest known period without rain in the midst of the rainy season in the history of the station. In California the precipitation was likewise far below the average, a condition that existed also in several preceding months. Some relief occurred in this State, however, toward the end of the month, which improved the situation somewhat temporarily, but there is still a large deficiency in the season's precipitation, which, if not made up during the spring months, will threaten seriously many of the industries of the State which depend so largely upon a normal supply of water.

SNOWFALL.

Snowfall during the month was light in the Ohio and middle and upper Mississippi Valleys, ranging from only a trace to about 7 inches, while the monthly totals were

mostly from 10 to 12 inches in the region of the Great Lakes. In the Northeast, however, the snowfall was very heavy, ranging from about 25 to more than 60 inches, most of which remained unmelted at the close of the month. The snowfall was light in most of the western mountainous districts and this, coupled with the deficiency during the preceding months of the winter, renders prospects unfavorable for an adequate supply of water for irrigation during the coming season. This condition exists most acutely in the mountains of California and thence northward to Washington.

RELATIVE HUMIDITY.

In the Rocky Mountains and Great Plains, also over the far Southwest, the relative humidity was very generally above the normal, the excess being well-pronounced in Colorado and thence southward, including Arizona and western Texas. In the central valleys and eastern districts excesses and deficiencies were observed indiscriminately, except in New England, where an excess was the rule. In the far West there was a well-defined deficiency which closely outlined the region of deficient precipitation.

SPECIAL FORECASTS AND WARNINGS—WEATHER AND CROPS.

WEATHER WARNINGS.

By ALFRED J. HENRY, Supervising Forecaster.

[Washington, Mar. 13, 1920.]

Strong winds.—The outstanding feature of the month was the fact that well-developed cyclonic systems with circular or oval isobars did not pass inland from the Pacific or southeastward from the Canadian Northwest. On the other hand, the low-pressure systems of the month west of the Appalachians were in the form of extensive NE.-SW. troughs of low pressure in which several centers of minimum pressure appeared. When these troughs approached Atlantic coast districts some one of the shallow depressions within them would develop into an intense cyclone which would move rapidly northeastward. Four such intense cyclones passed over New England and the Canadian Maritime Provinces during the month, each of which was attended by high winds and heavy snow. In addition to these four major storms, a number of minor disturbances approached the coast and made it necessary to issue warnings. In all, warnings of strong winds were issued on nine different occasions, the initial dates of the storm periods being as follows: 2d, 12th, 14th, 17th, 18th, 19th, 24th, 28th, and 29th. The details of each warning follow:

2d—The great sleet storm in New England and Middle Atlantic States.—High pressure over the Middle Atlantic States and the Atlantic to an unknown distance to the eastward in connection with relatively low pressure off the east Florida coast made it necessary to issue warnings for strong northeast winds, Jacksonville to Hatteras, and these warnings were subsequently extended to Eastport, Me., changed to northwest, Hatteras to Provincetown, Mass., on the 4th and continued from that direction on the 5th and 6th, respectively. The display which began on the south coast on the 2d was not definitely concluded on the New England coast until 10 a. m. of the 8th.

It seems probable that the heavy fall of sleet in portions of the Middle Atlantic and southern New England States on the 4th, 5th, and 6th may be attributed to the underrunning of warm southerly winds by a cold northeasterly current out of the great northern HIGH which apparently blocked the passage of the southern LOW on those dates.

Space will not permit a recital of the damage to beach property due to the waves of the record-breaking high tides of this storm.

12th.—A shallow depression along the middle Gulf coast and rapidly falling pressure made it necessary to issue warnings for strong northeast winds from Jacksonville to Fort Monroe, Va., on the 12th. The warnings were subsequently extended to Eastport, Me.

14th.—During the afternoon of the 14th a secondary disturbance developed over Virginia, the barometer falling 0.35 inch in 12 hours. By the morning of the 15th a cyclone of much intensity with two centers appeared, one center being over southern New England, the other one over the Province of Ontario. Fresh, shifting gales attended this storm in its movement over New England.

17th.—The display of the 17th was a failure; the winds did not attain the strength anticipated.

18th.—Special observations at noon of the 18th showed that a disturbance was developing over Florida. Assuming that it would move northeastward along the coast, northeast warnings were displayed, Jacksonville to Fort Monroe, Va. The storm, however, moved to the eastward over the Atlantic and the warnings failed.

19th.—On the morning of the 19th a cyclonic storm was centered southeast of Nantucket, evidently having developed from a shallow depression of the 18th over North Carolina. Northwest warnings were immediately displayed from Delaware Breakwater to Eastport, Me. This storm subsequently increased very much in intensity.

24th.—Special observations on the 24th showed that a shallow depression centered over North Carolina was increasing in intensity and warnings were accordingly issued for strong northwest winds, Delaware Breakwater to Nantucket. These warnings were subsequently extended to Eastport, Me. This storm increased greatly in intensity as it passed over the Canadian Maritime Provinces, the barometer reaching the low level of 28.62 inches on the morning of the 26th.

28th.—Warnings for strong easterly winds along the Atlantic coast, Norfolk to Boston, were issued 9:30 a. m. These warnings, owing to the erratic course pursued by the storm, were only partially verified.

29th.—Warnings for strong northwest winds along the east Gulf coast were issued at 1 p. m. of this date. They were fully verified.

Heavy snow.—Heavy snow warnings were issued for New England on the 5th.

Cold waves.—Severe and widespread cold waves were notably infrequent during the month, there being but two occasions when the temperature fell sharply in the Washington Forecast District, viz., on the 15th and 29th.

Killing frost.—Warnings of killing frost in northern and central Florida were issued on the 15th, 16th, and 17th and again on the 26th, 27th, and 28th. Cold wave warnings were issued for north and central Florida on the 29th and for central Florida on the 15th and 26th. The temperature fell to and slightly below freezing on each of these dates.

WARNINGS FROM OTHER DISTRICTS.

New Orleans Forecast District.—The depressions that passed over the district were of slight intensity and did not require storm warnings; but on the 29th an area of high pressure, which had moved southeastward from the northern Rocky Mountain region, was attended by a "norther" on the west Gulf coast, for which northwest-storm warnings were issued the preceding night for Louisiana and the east coast of Texas and were verified. Verifying velocity was reached also at Corpus Christi.

On the morning of the 13th, with high pressure in the Northwest and a wide trough extending from the upper Mississippi Valley and the Lake region to New Mexico and western Texas, cold-wave warnings were issued for Oklahoma, northwestern Texas, and northwestern Arkansas. A cold wave occurred in Oklahoma and extreme northwestern Arkansas; but the temperature fall was less marked in northwestern Texas, owing to the persistence of a shallow area of relatively low pressure over New Mexico, which was attended by easterly to southerly winds and snow at Amarillo, Tex.

An area of high pressure over the central portion of the country on the 15th was accompanied by unusually low temperatures at 8 p. m. and a cold wave was forecast for northern Louisiana and the northern portion of east Texas. Temperatures below freezing occurred as forecast, but the temperature fall was less than that required for a cold wave, as the effects of the cold area passed and a reaction to warmer weather set in quickly.

A cold-wave warning for Oklahoma and extreme northwestern Arkansas was issued during the afternoon of the 20th, on special observations, when the crest of a large area of high pressure was north of North Dakota and moving southward. A large fall in temperature occurred by the evening of the 21st, but temperatures on the morning of the 22d were higher than expected. The pressure remained low over Utah and only moderate cooling occurred during the night.

On the morning of the 28th a large area of high pressure extended southeastward from British Columbia to the Missouri Valley, with shallow depressions to the east and south. Cold-wave warnings were issued for Oklahoma, extreme northwestern Arkansas, and the northwestern portion of east Texas, and a cold wave occurred, with temperatures on the morning of the 29th in close agreement with the forecast. Cold-wave warnings were issued on the morning of the 29th for southern Louisiana and the southeastern portion of east Texas and conditions occurred generally as forecast except that the temperature remained above freezing on the Texas coast. A reading of 31°, usually low for the season, was recorded on the morning of March 1 at New Orleans.

Minimum temperature forecasts were issued when needed for the various portions of the district and stockmen were advised of all severe conditions. Warnings of frost or freezing temperature for the coast or adjacent sections were issued on the 4th, 14th, 15th, 16th, 25th, 26th, and 27th and were generally verified.

Fire-weather warnings for the forest reserves of Oklahoma and Arkansas were issued on the 20th. Conditions occurred as forecast, except with regard to precipitation, of which there was none of consequence on the 21st.—*R. A. Dyke.*

Chicago Forecast District.—A cold wave without warning occurred on the 2d in eastern North Dakota and northwestern Minnesota. The next cold wave overspread all sections from the Missouri Valley eastward during the 13th–14th and warnings were issued only for Minnesota and portions of Iowa and Wisconsin, the temperature falling lower than expected over the remainder of the area.

Cold-wave and cattle warnings were issued on the 19th–20th for the northern Rocky Mountain region, the Dakotas, and the western and central portions of Nebraska and Kansas. The warnings were fully verified only in North Dakota, as the cold wave lost force rapidly on account of the decrease in the intensity of the low-pressure area over the southern Plains States.

No warnings were issued during the remainder of the month and no cold waves occurred, except over a small area in the northern Rocky Mountain region on the 26th and the 28th.—*Chas. L. Mitchell.*

Denver Forecast District.—The month was one of generally fair weather without marked changes in temperature. No special warnings were issued: None were necessary. The important storm period of the month occurred between the 20th and 23d, when rains and snows were general and were successfully forecast. The rains in Arizona resulted in floods in the rivers of that State, particularly in the Gila River and the Colorado River at and below Yuma.—*E. H. Bowie.*

San Francisco Forecast District.—Due to the prevalence of high pressure areas which moved south from Alaska to the northern portion of this district before crossing the Rocky Mountains a woeful deficiency of precipitation occurred during the height of the usual rainy season.

Nearly all of the rain that fell was caused by two low pressure areas which moved from Alberta southwestward to California and Nevada. This is a most unusual track for Alberta storms to take. These storms did not cause any rain of consequence until they had moved far enough south to draw their supply of moisture from the ocean, and as a result the only rainfall of sufficient amount to do any good occurred in southern California. Snowfall in the mountains was markedly deficient. Temperatures, however, nearly everywhere were moderate and no severe cold spells were experienced.

Frost warnings were issued on 13 days for light to heavy frosts in some one or more portions of California. These warnings were as a rule verified, but the frosts were not heavy enough to cause serious damage to citrus fruit, though some almonds were injured during the latter part of the month.

One live-stock warning was sent to places in eastern Washington, eastern Oregon, and Idaho on the morning of the 19th, and it was fully verified.

Four storm warnings and eight small craft warnings were issued in portions of the district. While they were justified, the gales were not severe and no disasters so far as known occurred.—*E. A. Beals.*

RIVERS AND FLOODS, FEBRUARY, 1920.

ALFRED J. HENRY, Meteorologist, in Charge River and Flood Division.

Precipitation in northern districts was practically all in the form of snow and sleet; that which was in the form of rain was confined almost wholly to the Gulf and South Atlantic States, including Virginia. The rainfall of the 4th and 5th caused freshets and near floods in the James River of Virginia and practically all streams southward to Georgia.

In the Gulf of Mexico drainage there were no floods of consequence.

The Ohio and Cumberland Rivers were at flood stages in the lower portions at the close of January. Both rivers passed below flood stage in the early days of February and continued below throughout the remainder of the month.

The Mississippi, although carrying a large flow for a winter month, did not reach flood stage except at Arkansas City, Ark. At the close of the month the river was open south of Keokuk with stages generally well below flood.

Heavy rains in Arizona over the watershed of the Gila and tributaries from the 19th to 22d caused sharp rises in that stream during the closing days of the month. Damages to roadbeds, bridges, etc., were estimated at $314,000.

The usual details follow:

TABLE I.—*Flood stages during February, 1920.*

River and station.	Flood stage.	Above flood stages—dates. From—	Above flood stages—dates. To—	Crest. Stage.	Crest. Date.
ATLANTIC DRAINAGE.					
James:	*Feet.*			*Feet.*	
Columbia, Va	18	4	5	22.1	5
Richmond, Va	10	5	6	15.7	5
Roanoke:					
Randolph, Va	21	5	6	30.9	5
Weldon, N. C	30	5	8	40.2	7
Tar:					
Greenville, N. C	13	7	12	14.6	10
Neuse:					
Neuse, N. C	14	4	7	16.1	6
Smithfield, N. C	14	5	8	18.1	5
Cape Fear:					
Elizabethtown, N. C	22	6	8	25.8	6
Peedee:					
Cheraw, S. C	27	5	6	28.6	5
Santee:					
Rimini, S. C	12	(*)	(**)	16.7	2
Ferguson, S. C	12	(*)	(**)	13.8	3
Ocmulgee:					
Abbeville, Ga	11	2	5	12.4	3,4
EAST GULF DRAINAGE.					
Alabama:					
Montgomery, Ala	35	(*)	1	42.4	†29
Selma, Ala	35	(*)	6	45.1	†30
Etowah:					
Canton, Ga	11	4	4	14.9	4
Tombigbee:					
Demopolis, Ala	39	(*)	8	46.6	†31
Pearl:					
Jackson, Miss	20	(*)	9	27.6	†29
West Pearl:					
Pearl River, La	13	(*)	22	14.7	3
MISSISSIPPI DRAINAGE.					
Ohio:					
Henderson, Ky	33	(*)	2	38.3	†31
Evansville, Ind	35	(*)	3	39.6	1
Mount Vernon, Ind	35	(*)	3	38.6	†31
Shawneetown, Ill	35	(*)	4	38.1	1
Green:					
Lock No. 4, Woodbury, Ky	33	25	25	33.7	25
Lock No. 2, Rumsey, Ky	34	1	6	41.5	1

TABLE I.—*Flood stages during February, 1920*—Continued.

River and station.	Flood stage.	Above flood stages—dates. From—	Above flood stages—dates. To—	Crest. Stage.	Crest. Date.
MISSISSIPPI DRAINAGE—continued.					
Cumberland:	*Feet.*			*Feet.*	
Nashville, Tenn	40	(*)	1	44.1	†30
Clarksville, Tenn	46	(*)	2	47.9	†31–1
Lock D, Dover, Tenn	49	(*)	3	50.9	1
Mississippi:					
Arkansas City, Ark	42	6	13	43.2	10–11
Yazoo:					
Yazoo City, Miss	25	(*)	27	27.1	14–17
Tallahatchie:					
Swan Lake, Miss	25	(*)	20	28.2	3–5
Ouachita:					
Camden, Ark	30	(*)	1	36.6	†27
Monroe, La	40	2	15	40.3	7–10
Atchafalaya:					
Melville, La	37	13	19	37.4	16–17
White:					
Georgetown, Ark	22	(*)	4	22.8	†31–1
Black:					
Black Rock, Ark	14	(*)	3	20.2	†25
Cache:					
Patterson, Ark	9	(*)	6	9.1	1–5
Sulphur:					
Finley, Tex	24	(*)	1	26.0	†28–29
WEST GULF DRAINAGE.					
Trinity:					
Trinidad, Tex	28	(*)	4	35.6	1
Liberty, Tex	25	(*)	17	28.4	†31–2
Sabine:					
Bon Weir, Tex	20	(*)	15	22.0	†28
Orange, Tex	4	1	4	4.2	2–3
Neches:					
Rockland, Tex	20	(*)	2	27.2	†27
Beaumont, Tex	7	1	6	7.9	4
PACIFIC DRAINAGE.					
Colorado:					
Yuma, Ariz	25	24	26	31.7	25
Gila:					
Kelvin, Ariz	5	11	16	6.2	11
Do	5	21	27	5.6	22–24
Salt:					
Phoenix, Ariz	5	21	24	11.6	22

* Continued from January. ** Continued into March. † January.

MEAN LAKE LEVELS DURING FEBRUARY, 1920.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Mar. 4, 1920.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.* Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during February, 1920:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.91	579.95	570.80	245.01
Above or below—				
Mean stage of January, 1920	−0.17	−0.13	−0.58	−0.30
Mean stage of February, 1919	−0.16	−0.71	−1.41	−0.90
Average stage for February, last 10 years	+0.09	+0.01	−0.80	−0.47
Highest recorded February stage	−0.57	−2.77	−2.95	−2.66
Lowest recorded February stage	+1.15	+0.79	+0.17	+1.18
Average relation of the February level to—				
January level		0.0	0.0	+0.1
March level		−0.1	−0.1	−0.2

* Lake St. Clair's level: In February, 573.41 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, FEBRUARY, 1920.

By J. WARREN SMITH, Meteorologist in Charge.

The weather during February, 1920, permitted of the usual seasonal farm work, except that heavy sleet and snow interfered with out-door activities in the Northeast, and, owing to frequent rains little field work was possible during the latter part of the month in the more eastern sections of the country, particularly in the Southeast. At the close of the month field work was generally backward in the Southern States, due to frequent rains and wet soil. Corn planting was begun in the more Southern districts during the last half of the month, but at a considerably later date than usual. Some cotton was planted the latter part of the month.

The month as a whole was fairly favorable for winter wheat, although the alternate freezing and thawing the latter part was unfavorable in some sections, particularly in portions of the Ohio Valley, while the crop was unfavorably affected by lack of moisture in portions of Kansas and in California. Winter grains in general made satisfactory progress in the Southern States and were well protected by snow in the more northern districts. The seeding of spring grains made satisfactory progress in the Southwest, but this work was delayed in the Southeast on account of rainy weather and wet soil.

The month was generally favorable for stock in the western grazing districts, except the range was unfavorably affected by drought in California. The grazing area was extended considerably by the disappearance of snow and stock were reported in generally good condition. Under the influence of mild weather alfalfa and range grass in the Southwest started growth the latter half of the month. Conditions were generally favorable for lambing.

It was mostly favorable for truck crops in the South, except that low temperatures were harmful in the Southeast about the middle of the month and again near its close, when frost did considerable damage to tender truck. Some damage also was done to fruit, but no widespread harm to this crop was reported.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, February, 1920.

Section.	Temperature.								Precipitation.					
			Monthly extremes.								Greatest monthly.		Least monthly.	
	Section average.	Departure from the normal.	Station.	Highest.	Date.	Station.	Lowest.	Date.	Section average.	Departure from the normal.	Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	46.3	−0.9	Mobile	77	22	2 stations	11	16†	4.11	−1.37	Bay Minette	6.50	Guin	1.34
Arizona	49.4	+2.8	4 stations	80	1†	Fort Valley	4	12	2.40	+1.05	Williams	7.33	Naco	T.
Arkansas	45.0	+3.2	Prescott	79	4	Dutton	− 2	16	1.26	−2.15	Eldorado	3.18	Gravette	0.35
California	49.4	+0.9	Redding	87	2	Portola	− 2	20	2.80	−1.61	Nellie	12.68	2 stations	0.22
Colorado	28.5	+3.1	Las Animas	70	20	Glendevey	−32	29	1.13	+0.03	Cumbres	6.94	3 stations	T.
Florida	57.1	−2.9	2 stations	87	13	2 stations	19	17	5.40	+2.41	St. Augustine	21.50	Key West	1.38
Georgia	46.0	−1.4	Bainbridge	77	22†	Cornelia	9	16	4.59	−0.52	Quitman	7.22	Hartwell	1.58
Hawaii (January)	69.1	+0.8	5 stations	87	7†	Glenwood	43	25	7.20	+0.18	Wahiawa Mountain	26.24	Puu Oo	1.81
Idaho	30.7	+3.1	Orofino	66	27	Stanley	−25	25	0.43	−1.30	Spencer	1.56	2 stations	0.00
Illinois	30.0	+2.6	Harrisburg	69	2	2 stations	−14	15	0.66	−1.59	Casey	2.21	3 stations	0.13
Indiana	29.2	+0.1	Rome	68	2	2 stations	− 8	15†	0.90	−1.98	Bloomington	2.13	Wheatfield	T.
Iowa	24.0	+3.5	Keokuk	59	22	Elkader	−22	16	0.56	−0.59	Lacona	1.75	Mason City	0.04
Kansas	35.8	+4.7	2 stations	75	8†	Quenemo	− 2	16	0.34	−0.89	Clyde	1.74	10 stations	T.
Kentucky	35.7	+0.1	Earlington	71	2	4 stations	0	16	2.27	−1.33	Franklin	4.92	2 stations	0.79
Louisiana	54.2	+1.4	Houma	83	22	Calhoun	21	27	3.41	−1.00	Covington	7.45	Robeline	1.20
Maryland-Delaware	31.5	−1.3	Oakland, Md	62	2	Oakland, Md	− 5	16	4.17	+1.08	Millsboro, Del	8.57	Western Port, Md	1.43
Michigan	16.8	−1.4	Owosso	52	3	Reed City	−33	18	0.76	−1.05	St. Joseph	2.47	Humboldt	0.08
Minnesota	13.0	+2.5	St. Peter	44	3†	2 stations	−35	15	0.40	−0.32	Intenational Falls	1.60	Alexandria	0.00
Mississippi	48.8	+0.4	2 stations	79	21†	Corinth	14	16	3.07	−1.90	Biloxi	6.63	Hernando	0.83
Missouri	34.5	+3.2	Neosho	78	20	2 stations	− 5	15†	0.57	−1.68	Caruthersville	2.64	Lockwood	T.
Montana	25.4	+4.0	Three Forks	67	7	Glasgow	−30	15	0.50	−0.21	Adel	2.35	Trout Creek	T.
Nebraska	29.3	+4.7	Gothenburg	67	19	2 stations	−15	14†	0.52	−0.23	Auburn	1.72	2 stations	T.
Nevada	36.3	+2.0	Las Vegas	74	29	San Jacinto	− 8	26	0.71	−0.35	Searchlight	3.39	Jungo	0.00
New England	20.3	−1.6	Boston, Mass	52	18	Pittsburg, N. H	−45	1	4.77	+1.63	Portland, Me	8.97	Enosburg Falls, Vt	1.16
New Jersey	23.6	−6.2	2 stations	53	30	Culvers Lake	−14	26†	2.60	−1.21	Hammonton	3.53	Charlotteburg	1.61
New Mexico	40.8	+3.6	Artesia	86	23	Regina	− 5	1†	0.84	+0.08	Dulce	3.19	2 stations	T.
New York	20.0	−1.6	Angelica	55	2	Indian Lake	−38	1	2.88	+0.11	Dannemora	7.01	Hemlock	0.65
North Carolina	38.7	−2.8	Sanatorium	72	21	2 stations	− 3	16	4.47	+0.32	New Holland	8.77	Asheville	1.95
North Dakota	12.7	+4.8	Hettinger	53	8	2 stations	−36	14	0.30	−0.19	Pembina	1.70	7 stations	T.
Ohio	27.4	−0.4	Peebles	66	2	Hillhouse	− 7	19	1.05	−1.65	Clarington	2.73	Findlay	T.
Oklahoma	43.3	+4.2	4 stations	84	20	Pawhuska	− 6	16	0.43	−0.90	Broken Bow	2.42	2 stations	0.00
Oregon	37.5	+0.4	Brookings	75	17	Blitzen	−12	21†	0.35	−3.90	Brookings	2.51	2 stations	0.00
Pennsylvania	25.6	−1.7	Uniontown	62	2	Montrose	−20	1	2.44	−0.25	Somerset	5.23	Emporium	0.70
Porto Rico														
South Carolina	42.8	−4.1	Georgetown	76	12	Anderson	8	16	4.05	−0.30	Georgetown	6.99	Kent Spring	1.72
South Dakota	23.0	+5.8	Hot Springs	62	19	Roslyn	−23	15	0.63	+0.01	Greenmont	2.40	McIntosh	0.05
Tennessee	40.0	+0.3	Brownsville	73	20	Crossville	0	16	3.59	−0.82	New River	7.30	Covington	1.36
Texas	53.0	+2.7	3 stations	93	23	Lieb	8	28	0.77	−1.03	Bon Wier	3.74	6 stations	0.00
Utah	32.8	+4.2	St. George	68	27	Blacks Fork	−20	25	1.37	−0.08	New Harmony	5.74	Midlake	0.05
Virginia	34.0	−2.3	Dante	65	2†	Burkes Garden	− 4	16	4.67	+1.45	Runnymede	9.34	Woodstock	0.48
Washington	35.7	+1.0	Detroit	70	28	2 stations	1	10	0.50	−2.90	Quinialult	2.39	2 stations	0.00
West Virginia	31.3	−1.0	Glennville	69	2	Terra Alta	− 4	16	2.71	−0.36	Pickens	5.49	Wellsburg	1.49
Wisconsin	15.5	+0.2	Marinette	43	3	Winter	−42	18	0.53	−0.62	New London	1.19	Racine	0.20
Wyoming	23.7	+2.2	Burns	68	9	Moran	−37	29	0.80	−0.14	Middle Fork R. S	2.15	Powell	T.

* For description of tables and charts see this REVIEW, January, 1920, p. 54.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, February, 1920.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
New England.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	°F.	%	*In.*	*In*		*Miles.*							*0–10*	*In.*	*In.*
							23.5	− 2.1											78	4.88	+ 1.4									6.8		
Eastport	76	67	85	29.82	29.90	− .08	21.1	− 0.3	42	19	27	−15	1	15	30	20	16	78	6.40	+ 2.6	17	9,694	w.	54	ne.	19	7	5	17	7.1	37.2	30.3
Greenville, Me	1,070	6	....	28.70	29.92	.....	15.0	.....	35	3	24	−27	1	6	37	.....	.....	.....	.....	4.52	.....	16	.....	.....	.....	.....	.....	11	5	13	.....	44.8	36.0
Portland, Me	103	82	117	29.83	29.96	− .06	22.2	− 1.6	39	14	29	−16	1	15	28	20	15	74	8.97	+ 5.2	14	6,629	n.	44	e.	15	9	3	17	6.3	44.6	49.2
Concord	288	70	79	29.65	29.98	− .06	20.8	− 2.8	42	18	30	−23	1	12	34	.....	.....	.....	.....	3.23	− 0.1	13	3,866	nw.	23	nw.	27	8	9	13	5.9	35.0	28.5
Burlington	404	11	48	29.53	30.00	− .03	16.6	− 1.3	36	15	25	−28	1	8	45	.....	.....	.....	.....	1.74	+ 0.3	12	8,982	s.	48	s.	1	2	9	18	7.7	16.9	16.5
Northfield	876	12	60	28.99	29.98	− .07	15.9	− 1.3	48	2	27	−33	1	5	46	14	11	82	2.05	− 0.3	15	5,670	s.	28	n.	19	1	6	22	8.1	24.8	18.8
Boston	125	115	188	29.81	29.95	− .09	27.6	− 0.4	52	18	35	− 7	1	21	29	25	19	72	5.88	+ 2.3	13	8,497	w.	40	w.	15	6	10	13	6.8	32.5	16.9
Nantucket	12	14	90	29.91	29.92	− .12	30.1	− 2.5	47	6	36	9	27	24	25	28	26	85	6.99	+ 3.8	15	13,441	w.	60	ne.	5	6	6	17	7.2	8.2	3.0
Block Island	26	11	46	29.92	29.94	− .12	28.2	− 3.0	42	15	33	2	1	23	29	27	24	84	4.00	− 0.4	15	16,265	w.	70	ne.	5	11	2	16	6.6	10.8	6.5
Providence	160	215	251	29.77	29.96	− .09	26.4	− 2.6	46	3	33	− 8	1	20	28	25	20	78	4.56	0.0	13	10,518	nw.	56	nw.	27	5	10	14	6.5	22.8	16.8
Hartford	159	122	140	29.80	29.98	− .08	24.3	− 4.9	46	18	32	−14	1	16	30	22	17	75	5.08	+ 1.4	14	6,018	n.	35	nw.	27	5	10	14	6.6	24.6	15.4
New Haven	106	74	153	29.86	29.99	− .08	25.8	− 2.5	43	3	33	−10	1	19	26	24	19	74	4.78	+ 0.9	13	7,840	ne.	40	n.	5	8	8	13	6.1	15.4	6.0
Middle Atlantic States.							30.4	− 2.4											75	4.28	+ 1.0									6.5		
Albany	97	102	115	29.89	30.00	− .07	21.6	− 2.0	43	14	30	−20	1	13	38	20	16	82	3.36	+ 0.8	10	5,948	nw.	27	s.	14	7	10	12	6.2	23.9	20.0
Binghamton	871	10	84	29.04	30.01	− .07	21.8	− 2.9	46	14	30	−17	1	13	41	.....	.....	.....	.....	1.69	− 0.3	10	4,778	nw.	31	se.	14	3	9	17	7.7	19.9	14.0
New York	314	414	454	29.63	29.99	− .09	29.1	− 1.6	49	3	36	− 3	1	22	30	25	19	69	6.56	+ 2.7	15	15,052	nw.	65	nw.	15	6	10	13	6.9	24.2	4.5
Harrisburg	374	94	104	29.62	30.04	− .05	28.2	− 1.7	46	14	35	− 1	1	22	25	25	19	70	4.23	+ 1.4	11	5,720	nw.	26	nw.	15	6	5	18	7.1	21.0	4.5
Philadelphia	117	123	190	29.89	30.02	− .08	31.4	− 1.4	51	18	38	− 2	1	25	29	28	23	71	3.67	+ 0.2	13	7,724	nw.	33	nw.	25	7	12	10	5.9	5.9	0.2
Reading	325	81	98	29.66	30.03	.....	28.5	.....	52	18	35	− 2	1	22	25	25	20	72	3.03	− 0.6	12	6,330	nw.	28	w.	15	6	8	15	6.7	10.0	1.3
Scranton	805	111	119	29.12	30.02	− .06	24.8	− 2.1	46	14	32	− 5	1	18	29	22	18	78	4.74	+ 1.9	14	5,968	sw.	27	sw.	27	2	10	17	7.4	24.5	4.9
Atlantic City	52	37	48	29.94	30.00	− .11	31.2	− 1.8	47	15	37	7	1	26	30	28	24	78	5.54	+ 2.2	18	6,777	nw.	35	ne.	5	11	7	11	5.6	5.1	0.3
Cape May	18	13	49	30.01	30.03	− .08	31.8	− 2.3	45	15	37	7	1	27	26	29	26	82	4.89	+ 1.5	13	8,441	nw.	50	e.	4	10	8	11	5.7	5.2	0.5
Sandy Hook	22	10	57	29.97	29.99	.....	27.6	.....	45	18	33	1	1	22	24	26	23	83	3.90	.....	13	13,584	nw.	56	ne.	5	8	10	11	6.1	21.0	4.5
Trenton	190	159	183	29.78	30.00	.....	28.3	.....	51	18	35	− 3	1	21	28	25	21	76	4.27	+ 1.0	13	9,772	nw.	48	ne.	4	10	5	14	5.9	9.3	4.4
Baltimore	123	100	113	29.89	30.03	− .08	32.8	− 1.8	53	18	39	8	1	26	27	23	23	69	3.41	− 0.2	14	5,897	nw.	32	n.	4	8	9	12	6.3	5.5	0.5
Washington	112	62	85	29.90	30.03	− .08	32.1	− 1.8	55	18	40	9	1	26	28	28	22	69	3.47	− 0.1	14	6,679	nw.	35	nw.	15	6	9	14	6.9	7.7	0.5
Lynchburg	681	153	188	29.27	30.04	− .07	35.4	− 2.8	62	14	44	10	16	27	35	31	26	71	4.03	+ 0.4	11	6,510	nw.	37	ne.	4	8	8	13	6.3	2.9	T.
Norfolk	91	170	205	29.91	30.01	− .10	38.0	− 3.8	57	22	45	17	16	31	25	34	28	73	6.33	+ 2.5	14	10,704	nw.	54	ne.	4	9	8	12	6.1	0.1	0.0
Richmond	144	11	52	29.87	30.04	− .07	35.5	− 4.4	58	18	44	14	16	27	27	32	27	76	6.67	+ 3.5	12	6,956	nw.	36	ne.	3	6	9	14	6.4	3.6	T.
Wytheville	2,304	49	55	27.58	30.05	− .07	31.4	− 3.7	50	14	38	4	8	25	27	28	24	77	2.57	− 1.7	11	5,774	w.	32	w.	15	6	5	18	7.1	6.0	T.
South Atlantic States.							44.3	− 3.5											75	4.26	+ 0.1									5.5		
Asheville	2,255	70	84	27.64	30.08	− .05	35.7	− 2.8	58	22	44	6	16	28	38	31	27	77	1.95	− 2.8	14	5,602	nw.	28	n.	14	7	9	13	6.6	1.5	0.2
Charlotte	779	55	62	29.17	30.03	− .09	39.8	− 4.3	63	21	48	15	16	32	30	35	28	68	3.54	− 1.0	9	5,149	nw.	29	w.	14	12	3	14	5.8	T.	0.0
Hatteras	11	12	50	.....	30.00	− .11	43.1	− 3.5	64	13	49	24	27	37	22	.....	.....	.....	.....	6.43	+ 1.8	13	11,324	nw.	49	sw.	13	9	4	16	....	T.	0.0
Manteo	12	5	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Raleigh	376	103	110	29.61	30.03	− .08	38.8	− 4.5	65	21	47	16	16	30	31	35	32	80	5.49	+ 1.0	10	5,828	nw.	28	nw.	26	10	6	13	5.7	0.1	0.1
Wilmington	78	81	91	29.94	30.02	− .10	44.9	− 2.8	68	13	53	24	16	37	27	40	38	78	3.62	+ 0.1	12	5,184	w.	32	sw.	13	14	2	13	5.1	T.	0.0
Charleston	48	11	92	29.97	30.02	− .10	48.2	− 3.5	68	24	55	27	27	41	21	43	38	76	2.61	− 0.9	10	7,604	nw.	38	ne.	3	11	4	14	5.5	0.0	0.0
Columbia, S. C.	351	41	57	29.66	30.05	− .06	44.0	− 3.8	69	21	52	20	16	36	30	38	32	68	2.82	− 1.9	10	5,472	nw.	28	ne.	3	9	7	13	5.6	T.	T.
Augusta	180	62	77	29.84	30.03	− .09	45.4	− 3.6	69	21	54	21	16	37	31	41	36	76	3.40	− 1.1	10	4,925	nw.	25	nw.	24	13	1	15	5.4	0.0	0.0
Savannah	65	150	194	29.96	30.03	− .09	49.5	− 3.0	72	23	57	28	27	42	24	43	38	72	3.53	+ 0.1	12	9,219	nw.	43	w.	14	11	4	14	5.7	0.0	0.0
Jacksonville	43	209	245	29.99	30.04	− .08	53.9	− 3.0	74	24	61	32	27	47	23	48	45	81	9.16	+ 5.6	11	9,406	nw.	54	ne.	1	13	6	10	4.9	0.0	0.0
Greenville, S. C.	1,039	113	122	28.90	30.02	.....	40.7	.....	59	13	49	14	16	32	29	35	30	72	3.42	.....	9	6,916	ne.	37	w.	28	12	7	10	5.1	T.	0.0
Florida Peninsula.							63.7	− 3.6											75	2.03	− 0.6									4.6		
Key West	22	10	64	30.00	30.02	− .05	68.2	− 2.6	84	14	74	54	16	63	17	62	58	76	1.38	− 0.3	5	8,625	n.	48	w.	29	14	10	5	3.8	0.0	0.0
Miami	25	71	79	30.00	30.03	.....	64.2	− 4.6	82	25	73	41	16	56	27	57	54	74	1.60	− 1.2	7	6,479	nw.	34	w.	18	7	10	6	5.2	0.0	0.0
Sand Key	23	39	72	29.97	30.00	− .07	67.4	.....	77	14	71	53	16	64	15	62	59	75	.....	.....	.....	11,848	n.	50	n.	18	16	8	5	3.9	0.0	0.0
Tampa	35	79	92	30.01	30.05	− .05	58.6	− 3.7	76	12	66	38	17	51	27	51	47	74	3.10	− 0.2	6	5,085	nw.	29	nw.	29	10	8	11	5.4	0.0	0.0
East Gulf States.							48.6	− 2.2											73	4.12	− 0.8									5.8		
Atlanta	1,174	190	216	28.80	30.06	− .06	41.8	− 3.4	63	22	49	14	16	34	27	38	34	76	5.67	+ 0.9	11	9,669	nw.	42	nw.	15	7	7	15	6.3	0.1	0.0
Macon	370	78	87	29.65	30.06	− .06	45.5	− 3.4	70	23	54	19	17	37	32	40	34	71	3.56	− 1.2	10	5,308	nw.	29	nw.	29	12	2	15	5.7	0.0	0.0
Thomasville	273	49	58	29.74	30.05	− .07	50.6	− 4.4	74	23	59	26	17	42	29	45	41	75	5.77	+ 1.2	11	3,843	nw.	24	w.	12	9	7	13	6.0	0.0	0.0
Pensacola	56	149	185	30.02	30.09	− .02	52.5	− 3.0	70	23	59	30	29	46	26	48	44	76	3.18	− 1.5	10	9,660	n.	41	n.	29	12	4	13	5.4	0.0	0.0
Anniston	741	9	57	29.28	30.10	− .02	43.4	− 2.4	69	20	52	16	16	35	35	.....	.....	.....	3.28	− 1.5	12	5,158	nw.	27	nw.	29	9	7	13	5.8	0.2	0.0
Birmingham	700	11	48	29.33	30.12	.00	44.5	− 3.8	70	20	53	17	16	36	30	39	33	69	3.06	− 1.8	10	5,397	n.	23	n.	3	10	6	13	6.0	T.	0.0
Mobile	57	125	161	30.03	30.09	− .03	53.2	0.0	77	22	61	30	29	45	27	47	43	74	4.93	− 0.6	9	7,989	n.	46	n.	4	6	16	7	5.6	0.0	0.0
Montgomery	223	100	112	29.84	30.10	− .02	48.1	− 3.2	72	20	56	24	16	40	28	42	36	69	5.31	− 0.4	10	5,746	nw.	30	n.	29	10	6	13	5.4	0.0	0.0
Corinth	469	6	.....	.....	.....	.....	43.1	.....	71	20	52	14	16	34	33	.....	.....	.....	2.21	.....	9	.....	nw.	.....	.....	.....	.....	6	11	12	.....	1.5	0.5
Jackson	304	5	.....	.....	.....	.....	49.4	.....	75	20	58	25	27	40	36	.....	.....	.....	3.32	.....	11	.....	nw.	.....	.....	.....	.....	11	12	6	.....	.....	.....
Meridian	375	85	93	29.70	30.10	− .01	48.3	− 0.8	72	20	57	24	27	40	32	42	38	73	4.31	− 0.7	10	4,357	nw.	24	nw.	4	10	6	13	5.6	T.	0.0
Vicksburg	247	65	74	29.84	30.12	+ .02	50.6	− 0.3	76	19	59	28	27	43	31	45	40	73	2.70	− 2.1	9	4,818	n.	26	nw.	28	7	10	12	6.0	T.	0.0
New Orleans	53	76	84	30.04	30.10	+ .01	56.4	+ 0.1	80	22	64	35	29	49	28	51	47	78	3.60	− 1.0	7	5,112	n.	28	n.	29	9	7	13	5.6	0.0	0.0
West Gulf States.							52.2	+ 2.5											75	0.85	− 2.0									5.9		
Shreveport	249	77	93	29.85	30.13	+ .04	51.8	+ 1.8	76	21	60	30	16	43	26	46	41	71	1.43	− 2.3	6	5,106	nw.	26	n.	28	13	6	10	4.9	0.0	0.0
Bentonville	1,303	11	44	28.72	30.12	+ .02	39.8	+ 1.3	68	19	50	9	16	30	33	.....	.....	.....	0.66	− 2.9	7	3,962	nw.	28	s.	20	11	6	12	5.9	2.9	T.
Fort Smith	457	79	94	29.63	30.13	+ .03	44.2	+ 2.4	71	19	54	13	16	35	33	39	33	70	0.74	− 2.1	6	5,562	nw.	29	n.	13	10	8	11	5.3	0.5	0.0
Little Rock	357	139	147	29.73	30.12	+ .01	46.2	+ 2.1	70	20	54	17	16	38	28	41	35	70	1.16	− 3.2	5	6,048	n.	31	s.	20	8	12	9	5.6	T.	0.0
Brownsville	57	4	26	.....	.....	.....	65.4	.....	88	24	75	44	15	56	30	.....	.....	.....	0.75	.....	5	.....	n.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	30.08	30.10	+ .05	60.7	+ 3.0	87	23	67	40	29	54	24	56	54	85	0.20	− 1.9	4	7,408	se.	40	n.	29	5	7	17	7.1	0.0	0.0
Dallas	512	109	117	29.58	30.14	.....	50.4	.....	78	21	59	23	16	41	29	.....	.....	.....	0.79	.....	3	5,222	n.	33	nw.	28	8	7	13	6.1	0.0	0.0
Fort Worth	670	106	114	29.38	30.10	+ .03	50.4	+ 2.3	78	20	60	22	16	40	31	45	40	71	0.76	− 0.6	3	6,383	nw.	33	nw.	28	9	9	11	5.6	0.0	0.0
Galveston	54	106	114	30.06	30.12	+ .05	58.8	+ 3.2	74	22	64	40	29	54	19	55	51	80	1.80	− 1.4	6	8,031	n.	37	n.	20	10	11	8	5.4	0.0	0.0
Houston	138	111	121	29.96	30.11	.....	58.5	+ 4.5	83	23	67	36	15	50	26	.....	.....	.....	1.16	.....	4	5,737	nw.	29	s.	20	8	9	12	5.9	0.0	0.0
Palestine	510	64	72	29.58	30.12	+ .04	52.5	+ 1.6	76	21	61	29	29	44	29	47	42	75	1.02	− 2.5	7	5,233	n.	25	s.	20	5	12	12	6.6	0.0	0.0
Port Arthur	34	58	66	30.05	30.09	.....	57.2	.....	76	22	64	36	29	50	22	53	50	83	2.55	.....	5	6,469	n.	35	n.	29	8	13	8	5.9	0.0	0.0
San Antonio	701	119	132	29.37	30.11	+ .06	57.7	+ 3.3	88	23	67	34	29	48	30	51	47	74	0.27	− 1.6	7	5,275	ne.	34	n.	24	6	10	13	6.4	0.0	0.0
Taylor	582	55	63	29.53	30.14	+ .08	53.8	+ 2.5	84	23	63	30	16	45	33	.....	.....	.....	0.46	− 2.2	6	5,792	n.	33	n.	29	6	7	16	6.9	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, February, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F. 33.8	°F. −1.8	°F		°F	°F		°F	°F		°F	°F			% 75	*In* 2.11	*In.* −1.6		*Miles*							*0-10* 7.1	*In.*	*In.*
Chattanooga	762	189	213	29.28	30.11	−.02	41.2	−2.5	70	22	49	12	16	33	31		36	30			67	5.15	0.0	12	6,461	w.	37	nw.	29	6	9	14	6.6	0.7	T.
Knoxville	996	102	111	28.99	30.07	−.05	39.2	−1.6	64	2	47	12	16	32	33		35	29			72	4.94	−0.1	14	4,916	n.	26	sw.	17	5	7	17	7.5	0.5	T.
Memphis	399	76	97	29.72	30.14	+.03	43.6	+0.3	70	20	50	16	16	37	34		39	33			69	2.07	−2.4	10	6,239	n.	28	nw.	26	6	12	11	6.4	0.8	T.
Nashville	546	168	191	29.52	30.12	.00	39.4	−1.7	66	2	47	10	16	32	32		35	30			72	1.92	−2.5	12	6,734	nw.	34	nw.	26	5	5	19	7.1	4.3	1.5
Lexington	989	193	230	28.99	30.10	−.01	32.6	−3.0	62	2	39	2	16	27	28							2.11	−1.2	11	9,516	nw.	40	sw.	17	6	4	19	7.3	4.1	1.2
Louisville	525	219	255	29.52	30.12	+.02	34.2	−2.4	61	2	41	4	16	27	30		30	26			73	0.79	−3.0	5	9,090	nw.	39	sw.	17	7	5	17	6.4	0.3	T.
Evansville	431	139	175	29.64	30.13	+.02	35.0	−0.8	60	2	42	7	15	28	27		31	27			77	0.82	−2.3	7	8,135	nw.	34	sw.	17	6	11	12	6.4	2.9	0.2
Indianapolis	822	194	230	29.17	30.09	−.01	29.2	−1.5	58	2	36	−1	15	23	29		27	23			78	1.35	−1.8	8	8,767	w.	34	w.	15	3	10	16	7.5	2.6	T.
Terre Haute	575	96	129	29.46	30.10	.....	30.8	.....	57	2	37	1	15	24	25		27	23			74	1.92	.....	6	7,450	nw.	31	sw.	17	5	10	14	7.2	0.2	0.0
Cincinnati	628	11	51	29.39	30.10	.00	30.6	−1.8	61	2	37	0	16	24	31		28	25			82	1.30	−2.6	12	6,110	w.	29	sw.	10	7	4	18	7.0	5.4	0.0
Columbus	824	179	222	29.16	30.07	−.02	28.8	−2.2	55	2	35	0	16	23	26		26	22			78	1.12	−2.0	9	8,987	w.	39	w.	15	3	11	15	7.5	5.4	0.3
Dayton	899	181	216	29.06	30.05	.....	29.8	−0.2	59	2	36	0	16	24	27		27	24			80	1.13	−2.0	11	7,720	nw.	39	sw.	17	6	9	14	6.7	3.3	T.
Pittsburgh	842	353	419	29.12	30.06	−.03	28.2	−3.6	60	2	35	4	16	22	32		26	21			75	1.62	−1.1	14	9,268	nw.	40	w.	15	4	5	20	8.0	6.6	0.3
Elkins	1,947	59	67	27.92	30.07	−.03	28.8	−2.7	63	2	37	0	16	21	39		25	22			81	3.10	−0.2	24	4,580	w.	26	sw.	17	2	9	18	8.1	20.1	5.2
Parkersburg	638	77	82	29.41	30.09	−.01	32.1	−1.8	60	2	39	6	16	26	29		28	24			77	2.10	−1.2	17	5,000	nw.	28	w.	14	5	8	16	7.0	3.1	1.0
Lower Lake Region.							22.3	−2.3													77	1.35	−1.2									7.2		
Buffalo	767	247	280	29.10	30.02	−.04	19.9	−4.1	49	2	27	−5	1	13	38		18	15			81	2.35	−0.6	18	13,292	w.	58	w.	15	3	5	21	8.1	19.1	21.0
Canton	448	10	61	29.49	30.06	.....	15.4	−2.6	41	2	25	−30	1	6	52							2.22	−0.4	13	8,340	w.	43	sw.	17	9	9	11	5.6	22.2	25.0
Oswego	335	76	91	.....	30.01	−.05	21.2	−2.7	47	2	29	−15	1	14	35							1.21	−1.4	15	9,667	s.	40	w.	15	1	6	22	.....	29.3	28.5
Rochester	523	97	102	29.43	30.02	−.04	21.8	−2.1	49	2	29	−7	1	15	34		19	15			73	1.82	−1.1	17	7,706	w.	40	w.	16	4	9	16	7.4	18.7	18.0
Syracuse	597	97	113	29.35	30.02	−.05	21.4	−2.4	47	2	29	−15	1	14	38							1.90	0.0	16	9,177	nw.	48	w.	15	1	6	22	8.3	21.2	22.5
Erie	714	130	166	29.24	30.04	−.03	23.0	−3.1	52	2	30	0	16	16	28		20	17			76	1.13	−1.8	14	10,311	nw.	43	se.	1	3	8	18	7.2	12.7	5.3
Cleveland	762	190	201	29.21	30.06	−.01	24.5	−2.3	52	2	31	3	15	18	26		22	18			77	1.12	−1.6	15	10,081	w.	38	w.	15	4	4	21	7.8	10.3	5.7
Sandusky	629	62	103	29.35	30.06	−.01	25.0	−2.0	50	2	30	3	15	19	28							0.27	−2.2	9	9,100	w.	39	sw.	17	4	9	16	7.2	2.8	0.8
Toledo	628	208	243	29.36	30.08	+.01	25.0	−1.8	50	2	31	3	15	18	27		22	18			70	0.21	−1.8	6	10,194	w.	43	sw.	16	6	7	16	6.9	1.7	0.4
Fort Wayne	856	113	124	29.13	30.09	.....	25.6	−0.1	52	2	32	−4	16	19	35		23	19			76	0.20	.....	8	6,345	w.	31	nw.	3	4	9	18	7.2	1.2	T.
Detroit	730	218	245	29.24	30.06	.00	22.6	−2.4	47	2	29	0	16	16	25		21	17			78	0.97	−1.3	10	9,059	w.	42	sw.	16	6	9	14	6.7	9.4	2.1
Upper Lake Region.							17.2	−2.0													83	0.66	−1.2									6.7		
Alpena	609	13	92	29.35	30.05	+.02	14.7	−3.1	37	2	24	−13	18	6	29		13	10			84	0.69	−1.2	7	7,559	nw.	40	nw.	15	7	9	13	6.3	9.3	6.6
Escanaba	612	54	60	29.38	30.08	+.02	14.3	−1.0	35	9	23	−12	18	6	29		12	11			89	0.42	−1.0	7	5,711	n.	26	ne.	3	13	9	7	4.3	4.7	8.0
Grand Haven	632	54	89	29.36	30.08	+.03	20.8	−3.4	39	2	28	−8	19	14	32		19	16			82	1.11	−0.9	15	7,940	w.	36	w.	23	1	8	20	8.1	11.7	8.2
Grand Rapids	707	70	87	29.27	30.08	+.03	21.2	−4.3	44	2	28	−6	19	14	30		19	15			77	0.85	−1.1	9	4,268	w.	22	nw.	15	2	6	21	8.1	12.2	6.5
Houghton	684	62	99	29.31	30.08	+.03	12.4	−3.6	33	9	20	−14	4	4	36							0.78	−1.0	10	6,821	w.	40	w.	29	7	7	15	6.4	7.7	28.2
Lansing	878	11	62	29.08	30.06	.....	19.8	−1.8	48	2	28	−8	19	11	34		17	14			85	0.81	−1.3	15	4,500	nw.	23	sw.	16	2	8	19	7.7	11.2	3.4
Ludington	637	60	66	29.34	30.07	.....	19.4	.....	34	2	26	−6	19	12	31		19	16			86	0.82	.....	14	6,490	n.	39	w.	16	3	10	16	7.2	16.9	11.8
Marquette	734	77	111	29.25	30.10	+.05	15.6	−0.3	36	29	22	−8	15	9	30		13	11			85	1.05	−0.8	12	5,424	nw.	24	sw.	29	2	12	15	7.6	13.1	21.0
Port Huron	638	70	120	29.32	30.05	.00	19.2	−2.8	45	2	26	−5	16	12	20		17	15			85	0.79	−1.4	13	7,672	nw.	42	w.	15	4	10	15	6.8	13.4	9.6
Saginaw	641	69	77	29.34	30.06	.....	17.8	.....	46	2	26	−12	18	10	30		16	13			83	0.72	−1.4	10	5,451	nw.	29	sw.	16	8	4	17	6.8	8.5	7.0
Sault Sainte Marie	614	11	52	29.33	30.07	+.04	10.4	−3.0	31	6	20	−19	27	1	40		9	6			83	0.45	−1.0	5	5,417	nw.	31	nw.	26	10	7	12	5.7	4.8	16.8
Chicago	823	140	310	29.18	30.10	+.02	25.8	+0.4	49	2	32	−7	15	20	33		23	18			73	0.13	−2.1	7	8,237	nw.	34	ne.	3	6	7	16	6.9	1.7	0.0
Green Bay	617	109	144	29.38	30.08	+.02	15.8	−1.4	36	9	24	−13	16	8	28		14	10			77	0.47	−1.2	9	6,681	sw.	34	sw.	16	5	9	15	6.8	6.9	6.2
Milwaukee	681	125	139	29.32	30.08	+.02	21.6	−0.3	41	2	28	−10	15	15	37		20	16			81	0.45	−1.5	10	6,627	w.	30	sw.	16	6	9	14	6.4	6.1	4.0
Duluth	1,133	11	47	28.82	30.10	+.02	12.4	−1.2	32	6	20	−20	15	5	31		11	8			86	0.45	−0.6	10	8,822	nw.	48	nw.	13	10	10	9	5.5	4.5	8.3
North Dakota.							13.0	+6.0													85	0.16	−0.4									6.0		
Moorhead	940	8	57	29.13	30.21	+.10	10.7	+3.7	35	29	21	−24	15	0	39		9	7			87	0.20	−0.6	8	6,193	n.	32	n.	13	8	8	13	6.4	3.1	9.0
Bismarck	1,674	8	57	28.33	30.21	+.12	17.2	+8.9	42	16	27	−21	14	8	37		15	12			79	0.20	−0.3	4	6,891	nw.	38	nw.	1	9	11	9	5.3	2.0	T.
Devils Lake	1,482	11	44	28.48	30.15	+.04	8.0	+3.5	34	1	18	−30	14	−2	31		7	6			90	0.12	−0.4	5	7,231	w.	38	n.	12	9	8	12	5.9	2.0	5.4
Grand Forks	835	12	89	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....			.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Williston	1,872	41	48	28.10	30.16	+.05	16.1	+8.1	40	7	25	−22	15	7	33		15	13			87	0.13	−0.4	3	6,953	w.	30	nw.	27	10	11	8	5.3	1.3	0.3
Ellendale	1,457	10	56	28.54	30.17	.....	16.0	.....	38	12	26	−17	14	6	39		14	12			82	0.23	.....	8	9,903	nw.	48	n.	13	5	9	15	7.1	3.0	1.0
Upper Mississippi Valley.							25.7	+1.1													78	0.56	−1.2									6.6		
Minneapolis	918	102	208	29.09	30.12	.....	16.0	.....	35	2	23	−19	15	9	34		.....	.....			.....	0.46	−0.3	9	7,323	nw.	32	nw.	13	6	6	17	6.8	5.0	12.0
St. Paul	837	236	261	29.18	30.13	+.04	15.5	+0.5	34	2	23	−20	15	8	38		.....	.....			.....	0.57	−0.3	9	7,343	nw.	37	sw.	9	6	10	13	6.8	6.3	13.0
La Crosse	714	11	48	29.30	30.12	+.04	18.4	0.0	37	8	26	−15	15	11	38		.....	.....			.....	0.50	−0.6	7	3,436	nw.	18	w.	10	7	5	17	6.9	5.9	5.0
Madison	974	70	78	29.02	30.12	+.05	18.4	−1.2	38	2	26	−14	15	11	40		16	12			79	0.51	−1.0	9	6,083	nw.	33	ne.	3	4	8	17	7.2	6.1	6.4
Wausau	1,247	4	.....	28.60	30.00	.....	14.9	.....	36	7	23	−15	8	6	39		4	.....			.....	0.38	.....	8	.....	.....	.....	.....	.....	6	10	13	6.6	6.8	21.5
Charles City	1,015	10	49	29.01	30.14	+.04	19.2	+4.1	35	2	26	−16	15	12	42		18	16			88	0.21	−0.8	7	4,264	nw.	20	w.	16	4	7	18	7.2	3.2	2.0
Davenport	606	71	79	29.44	30.14	+.04	24.9	+1.1	45	2	32	−10	15	18	39		23	19			81	0.19	−1.4	3	5,866	nw.	26	nw.	28	5	9	15	6.3	1.4	0.0
Des Moines	861	84	97	29.19	30.14	+.03	25.3	+1.2	42	2	32	−7	15	19	44		24	20			80	0.74	−0.4	10	5,360	nw.	31	nw.	13	7	5	17	6.8	4.1	T.
Dubuque	698	81	90	29.36	30.15	+.06	21.1	−0.5	41	2	28	−14	15	14	39		16	16			79	0.47	−1.0	6	4,717	nw.	21	nw.	10	6	5	18	6.9	6.7	7.2
Keokuk	614	64	78	29.45	30.16	+.05	29.4	+2.8	59	2	37	−3	15	22	40		28	20			72	0.19	−1.5	4	5,852	n.	30	s.	16	9	8	12	5.8	0.3	T.
Cairo	356	87	93	29.72	30.12	.00	38.0	+0.4	65	2	45	11	16	31	28		34	29			73	1.68	−1.8	9	7,111	n.	31	sw.	17	6	10	13	6.6	4.3	1.6
Peoria	609	11	45	29.44	30.13	+.03	27.6	+1.7	54	2	35	−5	15	20	35		24	21			82	0.27	−2.5	5	5,578	nw.	27	sw.	16	9	6	14	6.0	0.2	0.0
Springfield, Ill.	644	10	91	29.41	30.11	+.01	30.4	+1.3	58	2	37	0	15	24	30		27	23			79	0.58	−2.3	5	6,643	nw.	26	sw.	17	7	11	11	6.1	0.3	0.0
Hannibal	534	74	109	29.54	30.14	+.03	31.0	+1.9	62	2	38	1	16	24	37		.....	.....			.....	0.68	−1.0	8	6,466	nw.	32	sw.	16	9	5	15	6.1	0.8	0.0
St. Louis	567	265	303	29.50	30.12	+.01	34.8	+1.3	64	2	42	5	16	27	30		30	25			70	0.74	−2.1	5	8,842	nw.	36	sw.	27	7	8	14	6.2	1.0	0.0
Missouri Valley.							29.8	+3.4													79	0.47	−0.6									6.1		
Columbia, Mo.	781	11	84	29.26	30.13	+.02	33.2	+3.1	63	2	41	2	16	25	37		.....	.....			.....	0.41	−1.8	5	6,352	nw.	28	w.	14	9	6	14	5.8	0.6	0.0
Kansas City	963	161	181	29.08	30.15	+.04	34.1	+4.2	61	2	42	3	15	26	35		30	24			70	0.07	−1.6	4	8,722	n.	37	sw.	16	12	8	9	5.2	0.6	0.0
St. Joseph	967	11	49	29.07	30.14	.....	31.8	.....	53	8	39	1	15	25	41		28	24			74	0.31	.....	4	6,505	nw.	30	nw.	13	8	8	13	5.9	0.1	0.0
Springfield, Mo.	1,324	98	104	28.68	30.13	+.02	36.9	+3.3	67	20	45	8	16	28	31		33	30			79	0.42	−2.0	6	7,177	nw.	29	n.	29	12	6	11	5.1	2.2	0.0
Iola	984	11	50	29.06	30.14	+.04	36.8	+4.8	69	20	47	8	16	27	34		.....	.....			.....	0.15	−1.0	4	5,068	n.	22	n.	28	9	10	10	5.8	0.1	0.0
Topeka	983	92	107	.....	.....	.....	33.8	+3.8	60	19	43	5	15	25	38		.....	.....			.....	0.17	−1.3	5	7,047	n.	33	nw.	25	11	6	12	5.5	0.3	0.0
Drexel	1,299	10	53	28.70	30.14	.....	27.6	.....	48	16	35	−4	15	20	47		25	22			86	0.37	.....	5	7,347	nw.	29	n.	25	6	4	19	7.0	3.5	0.0
Lincoln	1,189	11	84	28.84	30.16	+.06	30.8	+6.0	56	1	38	0	15	23	41		27	23			77	0.84	+0.1	4	6,958	n.	36	nw.	13	8	5	16	6.4	1.5	0.0
Omaha	1,105	115	122	28.93	30.16	+.05	28.9	+5.2	50	16	36	−3	15	22	46		26	22			78	0.83	0.0	6	6,778	nw.	36	nw.	13	7	3	19	7.2	2.8	0.0
Valentine	2,598	47	54	27.36	30.18	+.09	26.6	+5.4	62	19	37	−1	15	17	37		23	19			78	0.29	−0.3	9	7,272	nw.	31	nw.	22	10	4	15	5.6	4.8	0.0
Sioux City	1,135	94	164	28.90	30.17	+.05	24.9	+5.1	48	16	32	−12	15	18	52		23	21			86	0.67	+0.1	8	8,052	nw.	42	nw.	13	7	1	21	7.4	6.6	0.0
Huron	1,306	59	74	28.73	30.20	+.08	21.0	+8.1	44	5	30	−14	14	12	47		19	16			82	0.65	+0.2	6	7,542	nw.	36	nw.	9	7	7	15	6.5	6.2	0.3
Pierre	1,572	70	75	28.45	30.19	+.08	26.1	+9.2	54	7	35	−7	15	17	44		23	19			79	0.26	−0.2	4	6,410	nw.	37	nw.	13	12	5	12	5.0	3.2	0.3
Yankton	1,233	49	57	28.79	30.17	+.05	24.7	+6.5	50	10	32	−11	15	17	53		.....	.....			.....	0.90	+0.3	9	5,828	nw.	32	nw.	13	7	6	16	6.9	8.6	1.0

TABLE I.—*Climatological data for Weather Bureau stations, February, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	°F.	%	In.	In.		Miles									0–10	In.	In.
Northern Slope.							24.5	+ 3.0											75	0.77	0.0										4.9		
Billings	3,140	5					29.2		55	7	40	− 9	28	19	38					0.74		7		sw.				11	10	8		12.0	0.0
Havre	2,505	11	44	27.48	30.23	+ .16	21.3	+ 6.3	46	6	31	− 5	21	12	29	20	18	86		0.42	− 0.1	5	5,626	sw.	34	sw.	7	11	9	9	5.2	4.2	2.6
Helena	4,110	87	114	25.90	30.25	+ .14	25.5	+ 3.3	48	18	34	0	29	18	28	23	18	71		0.36	− 0.4	5	4,449	sw.	40	sw.	11	7	10	12	5.5	6.9	1.5
Kalispell	2,973	48	56	.....	30.25	+ .17	25.9	+ 2.1	45	19	34	4	28	18	30	.....	.....	76		0.26	− 1.2	5	2,860	nw.	25	sw.	7	8	9	12	....	1.3	T.
Miles City	2,371	26	48	27.59	30.26	+ .17	23.0	+ 6.2	48	7	32	−12	15	14	43	20	17	85		0.85	+ 0.3	5	4,599	nw.	32	nw.	12	9	15	5	4.6	8.5	2.5
Rapid City	3,259	50	58	26.66	30.23	+ .15	26.8	+ 3.3	57	1	37	− 8	15	17	34	22	14	63		0.64	+ 0.2	5	6,548	n.	38	nw.	17	13	7	9	4.7	6.6	1.9
Cheyenne	6,088	84	101	23.98	30.16	+ .13	26.8	+ 0.5	57	1	37	− 1	29	16	37	21	15	66		0.69	+ 0.1	8	8,774	nw.	60	w.	11	14	9	6	4.3	8.2	1.5
Lander	5,372	60	68	24.68	30.26	+ .18	20.2	− 1.6	51	18	32	−13	29	9	38	17	12	73		1.96	+ 1.3	8	2,030	sw.	20	e.	12	12	9	8	4.7	23.5	11.0
Sheridan	3,790	10	47	26.17	30.21	.....	27.0	.....	52	18	38	− 5	29	16	45	22	18	77		0.94	.....	9	4,019	nw.	37	nw.	7	10	9	10	4.8	12.4	1.9
Yellowstone Park	6,200	11	48	23.90	30.25	+ .15	21.4	+ 1.8	44	1	32	− 8	28	11	42	18	14	76		1.02	− 0.9	7	4,680	s.	31	sw.	11	9	13	7	5.0	12.3	15.6
North Platte	2,821	11	51	27.16	30.20	+ .13	29.6	+ 5.0	62	19	40	4	24	19	35	25	20	74		0.72	+ 0.3	3	5,160	nw.	26	nw.	13	11	8	10	5.0	6.5	0.0
Middle Slope.							36.0	+ 3.6											69	0.37	− 0.4										5.3		
Denver	5,292	106	113	24.73	30.13	+ .14	32.6	+ 1.5	59	7	42	9	14	23	32	27	20	64		0.48	0.0	7	4,803	ne.	35	ne.	12	12	7	10	6.4	7.3	T.
Pueblo	4,685	80	86	25.30	30.09	+ .09	34.8	+ 3.0	66	22	48	9	14	22	44	28	20	63		0.39	− 0.1	7	3,975	se.	32	nw.	12	9	12	8	5.1	3.0	0.0
Concordia	1,392	50	58	28.64	30.17	+ .08	33.9	+ 5.1	61	1	42	9	15	25	37	30	26	77		0.73	− 0.1	5	5,677	nw.	29	nw.	17	7	10	12	5.9	0.6	0.0
Dodge City	2,509	11	51	27.49	30.18	+ .12	35.1	+ 4.0	68	19	48	5	29	22	39	29	22	69		0.06	− 0.7	4	6,863	nw.	28	ne.	14	8	7	4.0	0.3	0.0
Wichita	1,358	139	158	28.66	30.14	+ .06	37.1	+ 4.1	67	19	47	12	16	28	35	32	26	71		0.32	− 0.8	2	8,721	n.	37	sw.	8	13	9	7	4.5	0.2	0.0
Altus	1,410	5	.....	.....	.....	.....	45.0	.....	81	20	56	20	16	34	45	.....	.....	.....		1.18	.....	3	.....	.....	.....	.....	.....	10	1	18	....	0.0	0.0
Muskogee	652	4	.....	.....	.....	.....	43.2	.....	73	19	54	4	16	32	36	.....	.....	.....		0.69	.....	7	.....	nw.	.....	.....	.....	10	12	7	....	1.0	0.0
Oklahoma	1,214	10	47	28.83	30.15	+ .08	42.2	+ 3.7	78	20	53	15	16	32	34	36	30	71		0.19	− 0.8	4	9,323	n.	45	n.	28	8	10	11	5.7	T.	0.0
Southern Slope.							48.2	+ 3.6											67	0.29	− 0.6										5.6		
Abilene	1,738	10	52	28.28	30.11	+ .06	49.0	+ 4.2	80	20	60	22	16	38	35	42	35	67		0.30	− 0.8	4	6,181	s.	36	sw.	28	7	2	20	6.8	0.0	0.0
Amarillo	3,676	10	49	26.31	30.11	+ .09	40.5	+ 3.3	78	22	53	12	29	28	48	34	29	72		0.18	− 0.7	4	7,497	n.	32	sw.	20	9	14	6	5.1	1.4	0.0
Del Rio	944	64	71	29.09	30.09	+ .09	57.2	+ 3.6	88	23	66	37	15	48	32	.....	.....	.....		0.02	− 0.9	2	5,626	se.	30	n.	24	6	10	13	5.9	0.0	0.0
Roswell	3,566	75	85	26.39	30.03	+ .05	46.0	+ 3.5	76	23	59	22	29	33	48	39	31	62		0.66	0.0	5	4,670	s.	27	e.	11	15	5	9	4.5	T.	0.0
Southern Plateau.							47.9	+ 3.1											60	1.04	+ 0.3										4.3		
El Paso	3,762	110	133	26.20	29.98	+ .03	53.4	+ 4.5	75	22	64	31	29	43	31	44	33	52		0.83	+ 0.4	4	7,730	w.	37	w.	9	12	11	6	4.7	0.0	0.0
Santa Fe	7,013	57	66	23.20	30.00	+ .02	37.5	+ 5.5	53	19	47	18	29	28	29	32	26	69		1.12	+ 0.2	8	5,064	sw.	33	w.	23	10	6	13	5.2	7.3	0.0
Flagstaff	6,908	8	57	23.32	29.97	− .03	35.0	+ 4.2	53	18	46	8	12	24	38	31	.....	.....		3.60	.....	11	4,702	sw.	27	s.	8	14	8	7	5.8	8.0	0.0
Phoenix	1,108	76	81	28.85	30.02	+ .03	57.6	+ 3.2	76	29	68	39	11	47	33	50	44	66		1.46	+ 0.7	9	3,109	e.	20	nw.	10	13	9	7	4.6	0.0	0.0
Yuma	141	9	54	29.87	30.02	+ .02	60.5	+ 1.3	78	16	72	40	11	49	30	52	44	61		0.66	0.0	5	3,348	n.	25	n.	6	16	6	7	3.4	0.0	0.0
Independence	3,957	9	41	26.01	30.08	+ .02	43.6	− 0.1	64	13	55	27	20	32	33	35	25	52		1.15	+ 0.4	7	4,359	nw.	36	w.	19	18	7	4	3.8	2.0	0.0
Needles	488	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Middle Plateau.							35.2	+ 2.2											67	0.78	− 0.4										4.2		
Reno	4,532	74	81	25.50	30.11	+ .03	38.2	+ 2.6	62	14	51	17	21	25	40	32	24	61		0.38	− 1.5	7	3,367	w.	37	w.	19	19	5	5	3.0	3.2	0.0
Tonopah	6,090	12	20	24.06	30.07	.....	35.7	.....	53	16	44	18	25	28	24	30	22	59		0.42	− 0.4	4	5,108	w.	35	se.	20	16	8	5	3.5	5.0	0.0
Winnemucca	4,341	18	56	25.68	30.15	+ .06	34.5	+ 1.2	58	15	48	14	11	21	42	29	22	66		0 24	− 0.7	5	4,501	ne.	27	ne.	8	19	3	7	2.9	2.4	0.0
Modena	5,475	10	43	24.63	30.08	+ .04	31.8	+ 0.2	53	28	42	− 1	12	22	37	28	23	73		1.67	+ 0.4	11	5,202	sw.	37	sw.	22	11	3	15	5.6	11.3	0.0
Salt Lake City	4,360	147	189	25.68	30.12	+ .04	37.4	+ 4.5	54	21	45	24	26	30	24	32	27	69		1.14	− 0.3	7	3,983	nw.	32	se.	19	14	3	12	4.7	1.0	0.0
Grand Junction	4,602	60	68	25.44	30.10	+ .06	33.9	+ 2.4	56	21	43	13	14	25	27	30	26	70		0.83	+ 0.2	9	2,731	nw.	22	w.	23	10	8	11	5.2	7.7	0.0
Northern Plateau.							35.3	+ 3.2											73	0.20	− 1.2										4.7		
Baker	3,471	48	53	26.56	30.22	+ .10	33.6	+ 5.7	54	18	43	15	22	24	27	30	26	74		0.04	− 1.4	2	3,804	se.	19	se.	26	18	4	7	3.6	0.4	0.0
Boise	2,739	78	86	27.30	30.23	+ .11	35.4	+ 1.4	59	18	43	20	22	28	29	32	27	71		0.35	− 1.1	3	2,670	nw.	21	se.	26	14	6	9	4.4	5.2	0.0
Lewiston	757	40	48	.....	30.24	+ .15	39.0	+ 2.8	57	18	48	23	29	31	28	.....	.....	.....		0.13	− 1.2	4	1,848	e.	22	w.	18	11	8	10	5.0	0.1	0.0
Pocatello	4,477	60	68	25.54	30.17	+ .07	33.3	+ 5.2	53	18	42	17	9	24	29	29	24	72		0.46	− 0.4	6	4,391	se.	28	se.	7	13	10	6	4.3	5.3	0.0
Spokane	1,929	101	110	28.16	30.28	+ .19	33.4	+ 3.3	50	18	41	21	9	26	25	30	25	72		0.09	− 1.9	2	3,215	ne.	24	sw.	7	11	6	12	5.3	0.5	0.0
Walla Walla	991	57	65	29.17	30.27	+ .16	37.1	+ 0.7	59	18	44	24	15	30	26	34	30	78		0.10	− 1.5	3	2,211	s.	19	s.	6	13	6	10	5.4	0.6	0.0
North Pacific Coast Region.							41.6	0.0											80	0.47	− 5.0										5.0		
North Head	211	11	56	29.99	30.23	+ .17	42.6	− 0.5	57	28	47	33	16	38	17	40	37	81		0.42	− 5.6	5	6,663	n.	48	nw.	18	15	6	8	3.9	0.0	0.0
North Yakima	1,071	4	.....	.....	.....	.....	36.3	.....	62	12	47	20	22	25	38	.....	.....	.....		0.04	.....	.....	.....	ne.	.....	.....	.....	18	2	9	....	.....	.....
Port Angeles	29	8	53	30.24	30.27	.....	39.2	.....	51	6	46	28	21	32	22	.....	.....	.....		0.44	− 2.7	3	3,883	s.	33	ne.	26	9	6	14	5.8	0.0	0.0
Seattle	125	215	250	30.14	30.27	+ .21	40.3	− 0.2	55	28	46	30	9	34	21	38	34	80		0.34	− 3.6	2	3,883	ne.	35	sw.	6	8	5	16	6.4	0.0	0.0
Tacoma	213	113	120	30.03	30.26	+ .20	39.8	− 0.6	56	29	46	28	11	33	28	38	35	84		0.34	− 5.0	1	3,496	se.	35	e.	27	9	7	13	6.3	0.0	0.0
Tatoosh Island	86	7	57	30.13	30.23	+ .23	43.2	+ 2.2	54	28	46	36	26	40	11	41	39	85		1.43	− 7.6	4	10,507	e.	55	e.	28	18	4	7	3.8	0.0	0.0
Medford	1,425	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Oreg	153	68	106	30.06	30.23	+ .15	42.2	+ 0.9	60	25	50	30	23	34	27	38	33	72		0.16	− 5.8	1	3,921	nw.	33	e.	27	13	8	8	4.5	T.	0.0
Roseburg	510	9	57	29.64	30.20	+ .10	41.2	− 1.4	63	26	51	24	25	32	38	38	34	77		0.17	− 4.6	2	1,442	nw.	18	s.	28	9	15	5	4.5	0.0	0.0
Middle Pacific Coast Region.							49.5	+ 0.5											70	1.27	− 3.2										4.0		
Eureka	62	73	89	30.08	30.14	+ .03	46.0	− 0.8	60	10	52	32	22	40	24	44	41	83		2.11	− 5.2	5	3,752	se.	33	n.	7	10	9	10	5.1	0.0	0.0
Mount Tamalpais	2,375	11	18	27.58	30.08	− .02	46.4	+ 0.8	61	18	52	31	20	41	19	41	35	68		1.43	− 4.5	6	10,059	e.	56	n.	8	18	5	6	3.4	T.	0.0
Point Reyes Light	490	7	18	29.52	30.04	.....	49.8	+ 0.6	60	8	54	42	20	46	13	.....	.....	.....		1.45	.....	8	9,662	nw.	50	s.	27	12	4	13	5.4	0.0	0.0
Red Bluff	332	50	56	29.73	30.10	− .01	50.6	+ 1.4	77	17	64	30	11	38	40	43	33	57		1.00	− 2.8	6	3,775	nw.	31	nw.	7	21	2	6	2.5	0.0	0.0
Sacramento	69	106	117	30.01	30.08	− .01	50.4	+ 0.2	71	18	62	33	22	39	36	46	40	68		0.81	− 2.4	6	4,422	se.	35	nw.	8	21	3	5	2.7	0.0	0.0
San Francisco	155	208	243	29.91	30.08	− .02	52.8	+ 1.5	70	7	59	42	21	46	22	47	42	74		1.23	− 2.6	6	5,103	w.	30	ne.	9	16	7	6	3.9	0.0	0.0
San Jose	141	12	110	29.93	30.08	.....	50.2	− 0.4	70	7	61	32	21	39	34	.....	.....	.....		1.04	− 1.6	6	3,383	se.	25	n.	8	13	6	10	4.7	0.0	0.0
South Pacific Coast Region.							55.2	+ 2.4											74	2.28	− 0.2										5.0		
Fresno	327	89	98	29.73	30.09	+ .01	52.2	+ 3.0	70	18	62	37	24	43	28	47	41	70		1.54	+ 0.2	6	3,214	nw.	21	nw.	20	17	6	6	3.3	0.0	0.0
Los Angeles	338	159	191	29.70	30.07	+ .01	57.6	+ 2.5	82	6	65	43	11	50	27	52	48	76		2.37	− 0.6	11	4,026	ne.	26	ne.	29	9	5	15	5.9	0.0	0.0
San Diego	87	62	70	29.96	30.06	.00	56.8	+ 2.2	76	6	63	42	11	50	24	52	49	80		2.87	+ 0.8	8	3,971	nw.	36	s.	8	8	10	11	5.9	0.0	0.0
San Luis Obispo	201	32	40	29.86	30.08	− .03	54.4	+ 1.9	76	6	64	33	12	45	32	48	43	72		2.36	− 1.4	10	2,546	nw.	20	ne.	7	10	11	8	4.8	0.0	0.0
West Indies.																																
San Juan, P. R	82	8	54	29.90	29.98	.....	75.6	.....	87	25	82	67	22	70	18	.....	.....	.....		3.15	+ 0.6	18	6,677	e.	32	e.	20	11	12	6	4.7	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.74	29.86	− .02	80.2	− 0.1	92	25	89	68	7	72	22	71	69	73		T.	− 0.8	0	8,006	n.	31	n.	17	10	19	0	4.2	0.0	0.0
Colon	36	7	97	29.84	29.88	− .02	81.2	+ 1.5	87	26	86	72	25	77	14	74	72	76		0.54	− 1.1	10	10,768	n.	31	n.	27	12	14	3	4.3	0.0	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during February, 1920, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	9			0.12														0.08			
Albany, N. Y.	5-6			1.92														(*)			
Alpena, Mich.	23			0.24														(*)			
Amarillo, Tex.	10			0.09														(*)			
Anniston, Ala.	12			0.87														0.20			
Asheville, N. C.	3			0.88														0.22			
Atlanta, Ga.	3			3.10														0.41			
Atlantic City, N. J.	14-15			0.63														0.40			
Augusta, Ga.	12			1.25														0.32			
Baker, Oreg.	7			0.02														(*)			
Baltimore, Md.	14			1.48														0.18			
Bentonville, Ark.	13			0.28														0.06			
Binghamton, N. Y.	18			0.22														0.08			
Birmingham, Ala.	22			0.47														0.20			
Bismarck, N. Dak.	18			0.08														(*)			
Block Island, R. I.	15			0.66														0.32			
Boise, Idaho.	19-20			0.29														(*)			
Boston, Mass.	15			1.01														0.49			
Buffalo, N. Y.	14-15			0.54														(*)			
Burlington, Vt.	15			0.66														(*)			
Cairo, Ill.	9			0.48														0.16			
Canton, N. Y.	14-15			0.82														(*)			
Charles City, Iowa.	12-13			0.06														(*)			
Charleston, S. C.	12			0.74														0.33			
Charlotte, N. C.	23			0.60														0.38			
Chattanooga, Tenn.	22			1.83														0.39			
Cheyenne, Wyo.	22-23			0.32														(*)			
Chicago, Ill.	6			0.03														(*)			
Cincinnati, Ohio.	20			0.36														0.09			
Cleveland, Ohio.	25-26			0.32														(*)			
Columbia, Mo.	20-21			0.21														(*)			
Columbia, S. C.	12			1.17														0.29			
Columbus, Ohio.	21			0.28														(*)			
Concord, N. H.	5-6			0.86														(*)			
Concordia, Kans.	4-5			0.44														(*)			
Corpus Christi, Tex.	12			0.10														0.05			
Dallas, Tex.	11			0.52														0.17			
Davenport, Iowa.	5			0.09														(*)			
Dayton, Ohio.	21			0.46														0.17			
Del Rio, Tex.	9			0.01														0.01			
Denver, Colo.	12-13			0.26														(*)			
Des Moines, Iowa.	5			0.33														(*)			
Detroit, Mich.	23			0.36														(*)			
Devils Lake, N. Dak.	12-13			0.05														(*)			
Dodge City, Kans.	4			0.03														(*)			
Drexel, Nebr.	2-3			0.18														(*)			
Dubuque, Iowa.	13			0.24														(*)			
Duluth, Minn.	12-13			0.10														(*)			
Eastport, Me.	6			1.92														0.17			
Elkins, W. Va.	10			0.37														0.10			
Ellendale, N. Dak.	17-18			0.08														(*)			
El Paso, Tex.	9			0.15														0.15			
Erie, Pa.	5			0.38														(*)			
Escanaba, Mich.	9			0.16														(*)			
Eureka, Calif.	21			0.82														0.28			
Evansville, Ind.	21			0.32														0.10			
Flagstaff, Ariz.	8			0.68														(*)			
Fort Smith, Ark.	2			0.37														0.13			
Fort Wayne, Ind.	9			0.09														(*)			
Fort Worth, Tex.	11			0.40														0.13			
Fresno, Calif.	19			0.74														0.50			
Galveston, Tex.	12			1.25														0.45			
Grand Haven, Mich.	16-17			0.24														(*)			
Grand Junction, Colo.	4-5			0.31														(*)			
Grand Rapids, Mich.	16-17			0.34														(*)			
Green Bay, Wis.	22-23			0.17														(*)			
Greenville, S. C.	3			1.47														0.29			
Hannibal, Mo.	20-21			0.55														(*)			
Harrisburg, Pa.	4-5			2.59														(*)			
Hartford, Conn.	4-5			2.05														(*)			
Hatteras, N. C.	3-4			2.76																	
Havre, Mont.	19-20			0.22														(*)			
Helena, Mont.	12			0.15														(*)			
Houghton, Mich.	23-24			0.31														(*)			
Houston, Tex.	11			0.62														0.38			
Huron, S. Dak.	20-21			0.33														(*)			
Independence, Calif.	22			0.44														(*)			
Indianapolis, Ind.	20-21			0.82														(*)			
Iola, Kans.	3			0.11														0.07			
Jacksonville, Fla.	2			4.16														0.61			
Kalispell, Mont.	7			0.12														(*)			
Kansas City, Mo.	23			0.04														(*)			
Keokuk, Iowa.	5			0.11														(*)			
Key West, Fla.	18			1.08														0.68			
Knoxville, Tenn.	23			0.86														0.62			
La Crosse, Wis.	22			0.21														(*)			
Lander, Wyo.	22-23			0.64														(*)			
Lansing, Mich.	23			0.27														(*)			
Lewiston, Idaho.	21			0.05														(*)			
Lexington, Ky.	21			0.77														0.16			
Lincoln, Nebr.	4-5			0.54														(*)			
Little Rock, Ark.	28			0.36														0.17			
Los Angeles, Calif.	8			0.55														0.25			
Louisville, Ky.	21			0.44														0.11			
Ludington, Mich.	14-15			0.19														(*)			
Lynchburg, Va.	3			2.34														0.28			
Macon, Ga.	12			1.44														0.36			
Madison, Wis.	22-23			0.18														(*)			
Marquette, Mich.	23-24			0.26														(*)			

* Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Memphis, Tenn.	22			0.28														0.24			
Meridian, Miss.	28			0.70														0.36			
Miami, Fla.	18			0.96														0.32			
Milwaukee, Wis.	22-23			0.12														(*)			
Minneapolis, Minn.	5			0.14														(*)			
Mobile, Ala.	12	D. N. a. m.	5:45 p. m.	2.22	5:30 a. m.	6:03 a. m.	0.10	0.07	0.16	0.35	0.40	0.50	0.63	0.67							
Modena, Utah	8-9			0.48														(*)			
Montgomery, Ala.	2			1.85														0.32			
Moorhead, Minn.	24-25			0.09														(*)			
Mount Tamalpais, Calif.	1			0.59														(*)			
Nantucket, Mass.	5			2.69														0.31			
Nashville, Tenn.	22			0.38														0.25			
New Haven, Conn.	4-5			1.95														(*)			
New Orleans, La.	28-29	4:12 p. m.	D. N. a. m.	2.06	10:34 p. m.	11:01 p. m.	0.61	0.07	0.11	0.24	0.47	0.68	0.72								
New York, N. Y.	15			0.79														0.43			
Norfolk, Va.	3			2.44														0.50			
Northfield, Vt.	5-6			0.80														(*)			
North Head, Wash.	6			0.23														0.07			
North Platte, Nebr.	2-3			0.46														(*)			
Oklahoma, Okla.	9			0.09														0.04			
Omaha, Nebr.	4-5			0.62														(*)			
Oswego, N. Y.	3			0.36														(*)			
Palestine, Tex.	11			0.59														0.16			
Parkersburg, W. Va.	21			0.68														0.11			
Pensacola, Fla.	10			0.31														0.26			
Peoria, Ill.	9			0.11														(*)			
Philadelphia, Pa.	4-5			1.64														(*)			
Phoenix, Ariz.	10			0.36														0.30			
Pierre, S. Dak.	20			0.20														(*)			
Pittsburgh, Pa.	21			0.49														0.12			
Pocatello, Idaho.	22-23			0.37														(*)			
Point Reyes Light, Calif.	1			0.51														0.18			
Port Angeles, Wash.	6			0.42														0.16			
Port Huron, Mich.	9			0.17														(*)			
Portland, Me.	5-6			3.05														(*)			
Portland, Oreg.	6			0.16														0.05			
Providence, R. I.	5			1.42														(*)			
Pueblo, Colo.	8-9			0.13														(*)			
Raleigh, N. C.	3			3.00														0.33			
Rapid City, S. Dak.	19-20			0.52														(*)			
Reading, Pa.	4-5			1.17														(*)			
Red Bluff, Calif.	19			0.36														0.19			
Reno, Nev.	22-23			0.12														(*)			
Richmond, Va.	3-4			3.30														(*)			
Rochester, N. Y.	5-6			0.65														(*)			
Roseburg, Oreg.	28			0.14														0.05			
Roswell, N. Mex.	9			0.25														0.19			
Sacramento, Calif.	29			0.42														0.15			
Saginaw, Mich.	22-23			0.23														(*)			
St. Joseph, Mo.	3			0.14														0.11			
St. Louis Mo.	21			0.24														0.14			
St. Paul, Minn.	5			0.16														(*)			
Salt Lake City, Utah	22-23			0.39														(*)			
San Antonio, Tex.	12			0.07														0.06			
San Diego, Calif.	8			0.97														0.29			
Sand Key, Fla.†																					
Sandusky, Ohio.	23			0.09														(*)			
Sandy Hook, N. J.	15			0.59														0.30			
San Francisco, Calif.	1			0.41														(*)			
San Jose, Calif.	29			0.40														0.09			
San Luis Obispo, Calif.	2			0.49														0.18			
Santa Fe, N. Mex.	9-10			0.56														(*)			
Sault Ste. Marie, Mich.	23			0.21														(*)			
Savannah, Ga.	11			0.86														0.56			
Scranton, Pa.	4-5			1.83														(*)			
Seattle, Wash.	6			0.32														0.09			
Sheridan, Wyo.	14-15			0.31														(*)			
Shreveport, La.	28			0.46														0.35			
Sioux City, Iowa.	13			0.30														(*)			
Spokane, Wash.	26			0.05														(*)			
Springfield, Ill.	20			0.50														(*)			
Springfield, Mo.	13			0.14														(*)			
Syracuse, N. Y.	5-6			0.62														(*)			
Tacoma, Wash.	6			0.34														0.08			
Tampa, Fla.	18	D. N. a. m.	7:20 p. m.	2.57	12:42 p. m.	1:38 p. m.	1.16	0.07	0.28	0.48	0.61	0.68	0.76	0.82	0.92	1.03	1.12	1.26			
Tatoosh Island, Wash.	6			0.67														0.19			
Taylor, Tex.	28			0.18														0.17			
Terre Haute, Ind.	20-21			1.51														(*)			
Thomasville, Ga.	12	8:22 p. m.	D. N. p. m.	1.51	8:45 p. m.	8:57 p. m.	0.05	0.17	0.71	0.76											
Toledo, Ohio.	23			0.08														(*)			
Tonopah, Nev.	22			0.24														(*)			
Topeka, Kans.	5			0.10														0.05			
Trenton, N. J.	4-5			2.68														(*)			
Valentine, Nebr.	20			0.09														(*)			
Vicksburg, Miss.	28			0.72														0.38			
Walla Walla, Wash.	20			0.05														(*)			
Washington, D. C.	3-4			1.55														(*)			
Wausau, Wis.	22			0.14														(*)			
Wichita, Kans.	3			0.30														(*)			
Williston, N. Dak.	18			0.07														(*)			
Wilmington, N. C.	12			1.23														0.47			
Winnemucca, Nev.	27			0.09														(*)			
Wytheville, Va.	3			1.04														0.20			
Yankton, S. Dak.	20-21			0.52														(*)			
Yellowstone Park, Wyo.	21			0.42														(*)			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, February, 1920.*

Stations.	Altitude above mean sea level.	Pressure.			Temperature of the air.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.90	29.95	+0.03	24.5	+ 5.2	33.5	15.5	50	−14	5.06	+0.97	20.0
Halifax, N. S.	88	29.79	29.90	− .05	25.2	+ 2.8	32.6	17.8	47	−14	6.32	+0.16	14.3
Yarmouth, N. S.	65	29.81	29.88	− .11	26.7	+ 0.9	32.8	20.6	47	− 4	7.09	+2.35	15.2
Charlottetown, P. E. I.	38	29.84	29.88	− .07	20.9	+ 3.3	27.6	14.3	44	−13	5.37	+2.31	18.8
Chatham, N. B.	28	29.86	29.90	− .06	17.2	+ 4.7	25.8	8.5	42	−27	4.14	+0.98	28.9
Father Point, Que.	20	29.90	29.93	− .05	13.8	+ 2.3	20.3	7.3	31	−20	3.00	+0.79	30.0
Quebec, Que.	296	29.61	29.95	− .04	14.8	+ 3.0	22.0	7.6	41	−26	3.39	+0.12	33.9
Montreal, Que.	187	29.75	29.97	− .05	16.0	+ 1.5	23.4	8.6	37	−21	2.93	−0.14	29.3
Stonecliffe, Ont.	489	29.36	30.00	− .01	9.0	− 0.9	22.1	− 4.0	38	−26	1.72	−0.28	17.2
Ottawa, Ont.	236	29.71	29.99	− .03	13.0	+ 1.3	23.8	2.2	35	−25	1.94	−0.75	19.4
Kingston, Ont.	285	29.67	30.01	− .03	17.9	+ 0.1	27.3	8.5	38	−18	1.33	−1.21	13.3
Toronto, Ont.	379	29.60	30.03	− .01	20.1	− 1.4	28.0	12.3	46	− 9	1.62	−0.99	16.1
Cochrane, Ont.	930												
White River, Ont.	1,244	28.60	29.99	− .03	4.5	+ 4.3	18.8	− 9.8	28	−42	0.67	−0.85	6.7
Port Stanley, Ont.	592	29.38	30.05	− .01	20.2	− 2.6	28.9	10.6	36	−16	3.00	−0.21	29.8
Southampton, Ont.	656	29.28			14.1	− 5.8	23.5	4.7	37	−15	1.65	−1.25	16.5
Parry Sound, Ont.	688	29.29	30.03	+ .02	13.0	− 1.3	24.0	2.0	39	−20	1.77	−1.15	17.7
Port Arthur, Ont.	644	29.32	30.06	+ .01	13.6	+ 7.2	24.3	3.0	35	−18	0.10	−0.80	1.0
Winnipeg, Man.	760	29.26	30.15	+ .05	6.0	+ 7.6	16.8	− 4.9	32	−29	0.85	−0.13	8.5
Minnedosa, Man.	1,690	28.20	30.13	+ .05	6.9	+ 9.6	18.4	− 4.5	34	−35	0.42	−0.19	4.2
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.75	30.10	+ .02	13.2	+12.6	22.9	3.6	39	−30	0.62	−0.11	6.2
Medicine Hat, Alb.	2,144	27.78	30.13	+ .08	21.1	+ 9.9	31.1	11.1	44	− 5	0.30	−0.37	2.8
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.40	30.14	+ .07	17.5	+ 9.5	27.1	7.9	41	−20	0.30	−0.44	2.6
Calgary, Alb.	3,428	26.51	30.23	+ .24	26.1	+12.6	37.1	15.2	49	− 7	0.99	+0.36	9.9
Banff, Alb.	4,521	25.47	30.26	+ .31	20.5	+ 1.3	33.9	7.2	41	−15	1.09	+0.17	10.8
Edmonton, Alb.	2,150	27.76	30.13	+ .11	22.3	+14.0	33.6	11.1	44	−18	0.30	−0.37	2.9
Prince Albert, Sask.	1,450	28.47	30.13	+ .04	13.5	+16.5	25.7	1.3	40	−30	0.84	+0.15	8.4
Battleford, Sask.	1,592	28.30	30.13	+ .04	14.4	+14.3	26.1	2.7	40	−26	0.36	−0.01	3.6
Kamloops, B. C.	1,262	29.03	30.37	+ .41	28.9	+ 0.6	38.0	20.8	46	12	0.15	−0.64	T.
Victoria, B. C.	230	29.99	30.25	+ .25	41.5	+ 2.0	47.1	36.0	53	32	0.62	−3.48	0.0
Barkerville, B. C.	4,180	25.79	30.23	+ .32	23.0	+ 4.1	32.5	13.5	39	0	1.12	−1.94	10.5
Triangle Island, B. C.	680												0.0
Prince Rupert, B. C.	170												
Hamilton, Bermuda	151	29.93	30.10	− .01	63.1	+ 1.6	67.5	58.8	72	50	6.26	+1.82	0.0

SEISMOLOGICAL REPORTS.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Apr. 3, 1920.]

TABLE I.—*Noninstrumental earthquake reports, February, 1920.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1920.	*H. m.*		° ′	° ′			*Sec.*			
Feb. 9	2 20	Julian	33 05	116 37	5	1	5	Loud rumbling	Felt by many	J. H. L. Vogt.
	11 30	do			3	1	8	Rumbling	Felt by several	Do.
	11 30	Mesa Grande	116 45	33 12	3	1	13	Faint	do	E. H. Davis.
		MISSOURI.								
28	2 55	Springfield	37 10	93 10	5	1	10	Loud rumbling	Felt with much severity in Rolla and Lebanon, and at many other places.	W. B. Hare, U. S. Weather Bureau.
		WYOMING.								
2	0 45	Clark	44 46	109 10	3	1	15	Rumbling	Felt by several	A. C. Snow.

TABLE 2.—*Instrumental Reports, February, 1920.*

[For significance of symbols and abbreviations, and for a description of stations and instruments, see the REVIEW for January, 1920, pp. 62–63.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
		ALABAMA. *Spring Hill College, Mobile.*						
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 10	.....	O	22 07 24	.....	.....	.....	2,570	
		eP	22 12 38	.....	.....	.....	.....	
		iS	22 16 49	7	*1,000	*3,500	.....	
		L	22 18 57	6.5	*2,000	*3,000	.....	
		M	22 20 39	6.5	*8,000	*31,000	.....	
		F	23 32 00	.....	.....	.....	.....	
		ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*						
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 2	.....	eP_E	11 44 56	.....	.....	.....	.....	Probably the quake which caused destructive tidal wave on island of Makatea. L is the only well-defined phase.
		eP_N	11 40 26	.....	.....	.....	.....	
		L_E	12 03 10	23	.....	.....	.....	
		eL_N	12 04 00	.....	.....	.....	.....	
		M_E	12 08 10	19	50	.....	.....	
		M_N	12 07 26	18	.....	10	.....	
		F_E	13 59 ..	.....	.....	.....	.....	
		F_N	12 50 ..	.....	.....	.....	.....	
10	.....	eP_N	22 22 45	.....	.....	.....	.....	
		e_E	22 40 25	.....	.....	.....	.....	
		L_N	22 40 26	.....	.....	.....	.....	
		M_E	22 49 26	13	20	.....	.....	
		M_N	22 44 06	.....	.....	20	.....	
		F_E	23 32 ..	.....	.....	.....	.....	
		F_N	23 17 ..	.....	.....	.....	.....	
		ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*						
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 10	.....	eL_E	9 55 38	19	5	.....	.....	Nothing on N.
		F_E	10 12 ..	.....	.....	.....	.....	
10	.....	P_E	22 14 50	.....	.....	.....	.....	Nothing on N.
		$P_E R_1$	22 16 30	.....	.....	.....	.....	
		S_E	22 21 00	.....	.....	.....	.....	
		L_E	22 26 50	45	.....	.....	.....	
		M_E	22 37 32	14	20	.....	.....	
		C_E	22 46 ..	13	.....	.....	.....	
		F_E	23 24 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
		COLORADO. *Sacred Heart College, Denver.*						
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 2	.....	L_N	12 14 ..	.....	.....	.....	.....	Intermittent sinusoidals.
		L_E	12 12 ..	.....	.....	.....	.....	No preliminaries visible.
		F	12 19 ..	.....	.....	.....	.....	Much stronger on E.-W. Small amplitude, long period.
2	.....	L	12 22 ..	15–20	*250	.....	.....	Recurring of sinusoidal.
		F	12 33 ..	.....	.....	.....	.....	
2	.....	L	13 32 ..	.....	.....	.....	.....	
		M_E	13 41 ..	20	*500	.....	.....	Hardly perceptible on N.-S.
		F_E	13 44 ..	.....	.....	.....	.....	
5	.....	L_N	2 30 ..	.....	.....	.....	.....	Visible activity.
		F_N	3 44 ..	.....	.....	.....	.....	
28	.....			.....	.....	.....	.....	Visible activity at intervals during day. Stronger on E.-W.
		DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*						
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 2	.....	eP	11 46 *ca.*	.....	.....	.....	.....	Time corrections uncertain throughout.
		S	11 51 40	.....	.....	.....	.....	
		eL	12 08 30	.....	.....	.....	.....	
		L	12 31 ..	30	.....	.....	.....	
		L	12 40 ..	18	.....	.....	.....	
		L	13 30 ..	20	.....	.....	.....	
		F	14 20 *ca.*	.....	.....	.....	.....	
7	.....	eL	12 09 *ca.*	15	.....	.....	.....	Time correction uncertain.
		F	12 20 *ca.*	.....	.....	.....	.....	
10	.....	eL	10 15 ..	.....	.....	.....	.....	
		L	10 20 ..	18	.....	.....	.....	
		F	11 20 *ca.*	.....	.....	.....	.....	
10	.....	P	22 12 08	.....	.....	.....	2,400	Time corrections uncertain.
		S	22 16 04	.....	.....	.....	.....	
		L	22 17 50	20	.....	.....	.....	
		L	22 30 ..	16	.....	.....	.....	
		L	22 53 40	12	.....	.....	.....	
		F	24 00 00	.....	.....	.....	.....	
12	.....	P	0 31 18	.....	.....	.....	.....	
		S	0 35 18	.....	.....	.....	.....	
		eL	0 40 30	14	.....	.....	.....	
		F	0 50 *ca.*	.....	.....	.....	.....	
12	.....	P	17 53 58	.....	.....	.....	.....	
		S?	17 57 ..	.....	.....	.....	.....	
		F	18 20 *ca.*	.....	.....	.....	.....	
22	.....	P	17 50 20	.....	.....	.....	.....	Time corrections uncertain throughout. L indistinguishable.
		S	18 00 08	.....	.....	.....	.....	
		M	18 00 32	.....	*7,500	.....	.....	
		F	18 45 ..	.....	.....	.....	.....	After 18th. 1m. amplitudes very small.
28	.....	P	18 50 08	.....	.....	.....	.....	
		S	18 57 40	.....	.....	.....	.....	
		eL	19 08 20	.....	.....	.....	.....	
		F	19 25 ..	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 1	.....	P.....	13 42 48	18	.....	.....	.....	
		L.....	13 59 30	.....	.....	.....	.....	
		M.....	14 01 00	17	*100	.....	.....	
		C.....	14 04 ..	.....	.....	.....	.....	
		F.....	14 14 ..	20	.....	.....	.....	
2	.....	P_1.....	11 32 12	17	.....	.....	.....	
		P_2.....	11 36 24	.....	.....	.....	.....	
		L_1.....	11 44 30	.....	.....	.....	.....	
		L_2.....	11 49 18	.....	.....	.....	.....	
		M.....	11 56 30	19	*11,200	.....	.....	
		C.....	12 45 ..	19	.....	.....	.....	
		L_{rep}...	14 03 ..	.....	.....	.....	.....	
		F.....	15 27 ..	19	.....	.....	.....	
3	.....	P.....	7 03 30	18	.....	.....	.....	
		eL.....	7 07 18	.....	.....	.....	.....	
		M.....	7 12 30	17	*200	.....	.....	
		C.....	7 14 ..	.....	.....	.....	.....	
		F.....	7 26 ..	18	.....	.....	.....	
3	.....	P.....	15 21 00	15	.....	.....	.....	
		S.....	15 24 00	17	.....	.....	.....	
		L.....	15 28 12	.....	.....	.....	.....	
		M.....	15 33 30	18	*300	.....	.....	
		C.....	15 37 ..	19	.....	.....	.....	
		F.....	15 41 ..	.....	.....	.....	.....	
3	.....	eP.....	20 07 18	20	.....	.....	.....	
		L.....	20 12 18	.....	.....	.....	.....	
		M.....	20 20 00	17	*100	.....	.....	
		F.....	20 42 ..	.....	.....	.....	.....	
3	.....	eP.....	9 29 00	19	.....	.....	.....	
		M.....	9 41 00	18	*100	.....	.....	
		F.....	9 57 ..	18	.....	.....	.....	
7	.....	P.....	15 24 06	18	.....	.....	.....	Phases fairly definite but not consistent.
		S.....	15 40 00	16	.....	.....	.....	
		L.....	15 51 00	.....	.....	.....	.....	
		M.....	15 56 24	17	*500	.....	.....	
		C.....	16 00 ..	17	.....	.....	.....	
		F.....	16 51 ..	19	.....	.....	.....	
8	.....	P.....	5 59 00	19	.....	.....	.....	P very faint.
		L.....	6 20 12	.....	.....	.....	.....	
		M.....	6 26 24	17	*300	.....	.....	
		C.....	6 38 ..	16	.....	.....	.....	
		F.....	6 44 ..	20	.....	.....	.....	
9	.....	P.....	19 35 54	.....	.....	.....	.....	
		L.....	19 38 24	.....	.....	.....	.....	
		M.....	19 43 00	19	*100	.....	.....	
		F.....	20 00 ..	18	.....	.....	.....	
10	.....	P.....	9 22 18	18	.....	.....	.....	End overlaps the beginning of the next quake. L may be 30 or 40 sec. earlier.
		iS.....	9 29 00	16	.....	.....	.....	
		eL.....	9 36 00	.....	.....	.....	.....	
		M.....	9 44 18	17	*1,800	.....	.....	
		C.....	9 50 ..	16	.....	.....	.....	
10	.....	P.....	10 19 18	17	.....	.....	.....	
		eS.....	10 24 24	17	.....	.....	.....	
		eL.....	10 28 00	.....	.....	.....	.....	
		M.....	10 33 06	16	*600	.....	.....	
		C.....	10 39 ..	17	.....	.....	.....	
		F.....	11 10 ..	19	.....	.....	.....	
10	.....	eP.....	22 21 12	17	.....	.....	.....	
		iS.....	22 30 24	20	.....	.....	.....	
		eL.....	22 53 48	.....	.....	.....	.....	
		M.....	22 58 42	18	*500	.....	.....	
		C.....	23 11 ..	20	.....	.....	.....	
		F.....	25 15 ..	19	.....	.....	.....	
19	.....	eP.....	20 22 36	.....	.....	.....	.....	
		eL.....	20 29 00	.....	.....	.....	.....	
		M.....	20 31 00	20	*300	.....	.....	
		C.....	20 34 ..	.....	.....	.....	.....	
		F.....	20 44 ..	20	.....	.....	.....	
22	.....	iP.....	17 51 30	17	.....	.....	.....	Phases well defined, but not consistent. Possibly two quakes.
		iS.....	17 53 30	17	.....	.....	.....	
		L.....	17 57 00	.....	.....	.....	.....	
		M.....	17 58 00	17	*600	.....	.....	
		C.....	18 04 ..	20	.....	.....	.....	
		F.....	18 20 ..	20	.....	.....	.....	
25	.....	eP.....	23 02 24	.....	.....	.....	.....	Beginning at 23:14:30, there are 3 or 4 waves of 30 sec. period.
		eL.....	23 22 00	.....	.....	.....	.....	
		M.....	23 27 00	17	*300	.....	.....	
		C.....	23 31 ..	.....	.....	.....	.....	
		F.....	23 39 ..	18	.....	.....	.....	
27	.....	eP.....	7 27 42	.....	.....	.....	.....	
		eS.....	7 33 06	.....	.....	.....	.....	
		L.....	7 36 30	.....	.....	.....	.....	
		M.....	7 43 24	18	*600	.....	.....	
		C.....	7 47 ..	18	.....	.....	.....	
		F.....	8 01 ..	.....	.....	.....	.....	
27	.....	eP.....	10 52 42	.....	.....	.....	.....	
		L.....	11 00 00	.....	.....	.....	.....	
		M.....	11 05 54	16	*400	.....	.....	
		C.....	11 10 ..	20	.....	.....	.....	
		F.....	11 16 ..	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 2	.....	P.....	11 42 13	.....	.....	.....	8,400	
		PR_1...	11 47 33	.....	.....	.....	.....	
		S.....	11 51 54	22	.....	.....	.....	
		eL.....	12 11 ..	.....	.....	.....	.....	
		M.....	12 30 10	.....	*8,000	.....	.....	
		M.....	12 32 10	.....	*7,000	.....	.....	
		M.....	13 38 40	.....	*8,000	.....	.....	
		F.....	17 20 ..	.....	.....	.....	.....	
3	.....	eL.....	7 40 ..	18	.....	.....	.....	
		L.....	7 55 ..	16	.....	.....	.....	
		F.....	8 20 *ca.*	.....	.....	.....	.....	
7	.....	P.....	11 59 25	.....	.....	.....	2,760	
		S.....	12 03 50	.....	.....	.....	.....	
		eL.....	12 07 40	.....	.....	.....	.....	
		L.....	12 12 ..	15	.....	.....	.....	
		F.....	12 40 *ca.*	.....	.....	.....	.....	
7	.....	eL.....	16 19 *ca.*	.....	.....	.....	.....	
		L.....	16 23 30	18	.....	.....	.....	
		L.....	16 45 ..	15	.....	.....	.....	
		F.....	17 *ca.* ..	.....	.....	.....	.....	
8	.....	L.....	6 47 30	24	.....	.....	.....	
		F.....	7 40 *ca.*	.....	.....	.....	.....	
9	.....	eL.....	3 35 *ca.*	.....	.....	.....	.....	Possibly not seismic.
		F.....	4 *ca.* ..	.....	.....	.....	.....	
10	.....	P?.....	9 37 48	.....	.....	.....	.....	
		S?.....	9 47 32	.....	.....	.....	.....	
		L.....	10 08 30	18	.....	.....	.....	
		L.....	11 02 ..	18	.....	.....	.....	
		F.....	12 *ca.* ..	.....	.....	.....	.....	
10	.....	P.....	22 13 18	.....	.....	.....	2,990	
		S.....	22 18 ..	.....	.....	.....	.....	
		L.....	22 20 13	22	.....	.....	.....	
		M.....	22 37 30	.....	*16,000	.....	.....	
11	.....	F.....	1 *ca.* ..	.....	.....	.....	.....	
12	.....	P.....	0 32 02	.....	.....	.....	.....	
		S.....	0 37 07	.....	.....	.....	.....	
		L.....	0 43 ..	.....	.....	.....	.....	
		F.....	1 35 *ca.*	.....	.....	.....	.....	
12	.....	P?.....	17 52 15	.....	.....	.....	.....	
		S.....	17 57 15	.....	.....	.....	.....	
		L.....	18 03 *ca.*	18	.....	.....	.....	
		F.....	18 40 *ca.*	.....	.....	.....	.....	
20	.....	S?.....	12 08 10	.....	.....	.....	.....	
		eL.....	12 20 ..	.....	.....	.....	.....	
		L.....	12 29 ..	16	.....	.....	.....	
		F.....	13 20 *ca.*	.....	.....	.....	.....	
22	.....	P.....	17 47 18	.....	.....	.....	.....	
		S.....	17 56 35	.....	.....	.....	7,950	
		L.....	18 08 35	18	.....	.....	.....	
		F.....	19 10 *ca.*	.....	.....	.....	.....	
24	.....	eL.....	8 07 30	.....	.....	.....	.....	
		F.....	8 50 ..	.....	.....	.....	.....	
27	.....	eL.....	8 04 ..	.....	.....	.....	.....	
		L.....	8 11 ..	18	.....	.....	.....	
		F.....	8 30 *ca.*	.....	.....	.....	.....	
27	.....	eL.....	11 34 *ca.*	.....	.....	.....	.....	
		F.....	11 50 *ca.*	.....	.....	.....	.....	
28	.....	P.....	18 50 48	.....	.....	.....	6,200	
		S.....	18 58 34	.....	.....	.....	.....	
		L?.....	19 08 10	.....	.....	.....	.....	
		L.....	19 12 ..	24	.....	.....	.....	
		F.....	20 *ca.* ..	.....	.....	.....	.....	

* Trace amplitude.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 2	.....	eL_E...	12 35 26	.....	10	.....	.....	Nothing on N. This and the following one may be part of the same quake.
		F_E....	12 42 ..	.....	.....	.....	.....	
2	.....	eL_E...	13 29 19	.....	10	.....	.....	
		F_E....	13 35 ..	.....	.....	.....	.....	
10	.....	iP.....	22 12 56	4	.....	.....	.....	Felt in Porto Rico.
		S.....	22 17 00	.....	.....	.....	.....	
		eL.....	22 20 20	.....	.....	.....	.....	
		M_E....	22 24 22	.....	60	.....	.....	
		M_N....	22 27 20	6	.....	830	.....	
		C_E....	22 38 ..	.....	.....	.....	.....	
		C_N....	22 37 ..	.....	.....	.....	.....	
		F_E....	23 03 ..	.....	.....	.....	.....	
		F_N....	22 54 ..	.....	.....	.....	.....	
22	.....	P_E....	17 58 10	.....	.....	.....	.....	All the waves have a period of about 5 sec., indicating that it is probably an unusually large microseismic tremor.
		P_N....	17 58 09	.....	.....	.....	.....	
		M.....	17 58 27	5	80	30	.....	
		F_E....	18 00 ..	.....	.....	.....	.....	
		F_N....	18 02 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

MASSACHUSETTS. *Harvard University, Cambridge.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 2	.....	*O*.....	11 *postea*	.....	.....	.....	.....	E component stopped from trouble with the governor at 9h. 18m. N component undamped. Seismogram suggests two quakes, but 2d M may be Mrepi as recorded, indicating an epicenter distant 13,400 Km. *ca.*
		e_N.....	11 39 26	6	.....	.....	.....	
		e_E.....	11 44 51	10	.....	.....	.....	
		L.....	12 27 22	28	.....	.....	.....	
		M.....	12 38 33	19	.....	*500	.....	
		M.....	12 42 00	20	.....	*9,500	.....	
		L.....	12 38 51	46	.....	.....	.....	
		M_E.....	13 26 23	21	.....	*21,500	.....	
		M_E.....	13 35 36	18	.....	*4,500	.....	
		F?.....	14 55 *ca.*	.....	.....	.....	.....	
7	.....	O?.....	11 48 33	.....	.....	.....	3,723	P and F masked by microseisms. Distance obtained from L–S.
		S_N.....	12 01 21	8	.....	.....	.....	
		S_E.....	12 01 23	8	.....	.....	.....	
		eL_E.....	12 05 20	.....	.....	.....	.....	
		L_N.....	12 06 05	14	.....	.....	.....	
		iL_N.....	12 07 13	13	.....	.....	.....	
		M_E.....	12 07 47	14	.....	.....	.....	
		M_N.....	12 08 34	14	.....	.....	.....	
		F?.....	12 26 *ca.*	.....	.....	.....	.....	
7	.....	O.....	13 *postea*	.....	.....	.....	.....	N component out of commission before 13h. 29m. and E component before 13h. 28m.
		L_N.....	13 32 00	11	.....	.....	.....	
		M_N?.....	13 26 08	13	.....	.....	.....	
		L_E.....	13 36 32	20	.....	.....	.....	
		F.....	13 50 *ca.*	.....	.....	.....	.....	
7	.....	O?.....	16 *postea*	.....	.....	.....	.....	Doubtful record. Steady mass jerked W.
		i_E?.....	16 27 18	*	.....	.....	.....	
		L_E?.....	16 35 03 to 44 40	20?	.....	.....	.....	
8	.....	O.....	6 *postea*	.....	.....	.....	.....	Earlier and later phases in micros.
		L_N.....	6 51 39	24?	.....	.....	.....	
		L.....	7 00 24	15	.....	.....	.....	
		L_E.....	7 02 51	16?	.....	.....	.....	
		$F?_N$.....	7 09 ..	.....	.....	.....	.....	
10	.....	O.....	9 *postea*	.....	.....	.....	.....	
		e_E.....	9 41 48	.....	.....	.....	.....	
		e_E.....	9 50 24	14	.....	.....	.....	
		L_E.....	10 13 14 to 33 23	20	.....	.....	.....	Sinusoidal.
		F?.....	10 30 00	.....	.....	.....	.....	
		L_E?.....	11 09 20	20	.....	.....	.....	A decreased. L_{E1}? L_E 11 10 12 15.
		F?.....	11 44 *ca.*	.....	.....	.....	.....	
10	.....	*O*.....	22 07 32	.....	.....	.....	2,430	Probably north of Hayti.
		eP_N.....	22 12 32	2	.....	.....	.....	i from South.
		eP_E.....	22 12 33	.....	.....	.....	.....	
		S_N.....	22 16 31	.....	.....	.....	.....	
		S_E.....	22 16 43	.....	.....	.....	.....	
		M_E.....	22 20 18	.....	*56,000	.....	.....	L emerges from S without a long period phase and is difficult to fix.
		M_N.....	22 21 *ca*	.....	.....	*57,500	.....	
		M_N.....	22 22 00	.....	.....	*56,000	.....	
		C_N.....	22 47 00	14	.....	.....	.....	
11	.....	F_N.....	0 28 *ca*	.....	.....	.....	.....	
12	.....	*O*.....	0 26 17	.....	.....	.....	2,630	
		P_N.....	0 31 26	.....	.....	.....	.....	
		S.....	0 35 51	.....	.....	.....	.....	
		eL?.....	0 38 32	35	.....	.....	.....	
		L.....	0 38 43	15	.....	.....	.....	
		L.....	0 41 44	12	.....	.....	.....	Sinusoidal.
		L.....	0 43 32	10	.....	.....	.....	
		F.....	1 29 *ca*	.....	.....	.....	.....	
12	.....	L_N.....	17 58 22	13	.....	.....	.....	Unrest from 13h 40m at set-up to as late as 13d. 2h. 30m. *ca.*, periods above 10 sec. Motion less on E damped 1.5/1. Quite possibly nonseismic.
		L.....	18 01 36	13–10	.....	.....	.....	
		F?.....	19 03 *ca*	.....	.....	.....	.....	
22	.....	*O*.....	17 35 40	.....	.....	.....	8,580	Probably quake reported in Gori district, near 44° E. and 42° N., distance from which position to this station by cosinve-haersine formula is 8,599 km. S of this record displayed exceptional A for weak, distant, record. Overlapping from last.
		P_E.....	17 47 46	3	.....	.....	.....	
		P_N.....	17 47 48	2	.....	.....	.....	
		S_E.....	17 57 35	8	.....	.....	.....	
		S_N.....	17 57 40	8	.....	.....	.....	
		i_N.....	17 57 49	6	.....	.....	.....	
		i_E.....	17 57 49	7	W*2000	.....	.....	
		eL_N?..	18 13 50	15	.....	.....	.....	
		L_N.....	18 24 06	16	.....	.....	.....	
		L_N.....	18 24 12	20	.....	.....	.....	
		F_E.....	18 40 *ca*	.....	.....	.....	.....	
24	.....	e.....	8 13 *ca*	6	.....	.....	.....	
		L.....	8 13 42	16–20	.....	.....	.....	
		L_Ei?..	8 41 23	16	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

MASSACHUSETTS, *Harvard University, Cambridge*—Continued.

1920.								
Feb. 28	.....	*O*.....	18 postea	.....	.....	.....	.....	
		eP_N?..	18 50 44	3	.....	.....	.....	Masked by micros. Distance 6,150 km. to 7,100?
		S_N?...	18 58 28	8	.....	.....	.....	
		S_E?...	18 58 46	6?	.....	.....	.....	
		e_E.....	19 09 06	16	.....	.....	.....	
		eL_N?..	19 10 28	40	.....	.....	.....	
		e_E.....	19 10 48	16	.....	.....	.....	
		eL_N?..	19 10 49	30	.....	.....	.....	
		L_E.....	19 14 53 to 17 55	20	.....	.....	.....	Sinusoidal.
		C_N.....	19 18 20	.....	.....	.....	.....	
		F_E?...	19 36 *ca*	.....	.....	.....	.....	

NEW YORK. *Cornell University, Ithaca.*

1920.			*H. m. s.*	*Sec.*			*Km.*	
Feb. 2	.....	e_E.....	11 48 52	5	.....	.....	.....	
		$eL?_E$..	12 04 30	11	.....	.....	.....	
		L_E.....	12 24 40	30	.....	.....	.....	
		F_N.....	14 18 ..	.....	.....	.....	.....	
7	.....	L_E.....	12 07 45	15	.....	.....	.....	Earlier phases lost in micros.
		F.....	12 22 ..	.....	.....	.....	.....	
10	.....	P.....	22 12 55	4	.....	.....	.....	
		PR_{1E}..	22 13 31	4	.....	.....	.....	
		S.....	22 17 17	7	.....	.....	.....	
		L_E.....	22 18 55	23	.....	.....	.....	
		F.....	24 02 ..	.....	.....	.....	.....	

CANAL ZONE. *Department of Operation and Maintenance, Panama Canal, Balboa Heights.*

1920			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 2	.....	.....	.....	.....	.....	.....	.....	Slight movement from a distant quake between 11h. 30m. and 13h. 30m.; direction unknown.
2	.....	P_E.....	15 06 49	.....	.....	.....	232	Direction probably SW.
		P_N.....	15 06 52	.....	.....	.....	.....	
		S_E.....	15 07 14	.....	.....	.....	.....	
		S_N.....	15 07 17	.....	.....	.....	.....	
		M_E.....	15 07 20	.....	*1,000	.....	.....	
		M_N.....	15 07 24	.....	.....	*1,500	.....	
		F_E.....	15 09 30	.....	.....	.....	.....	
		F_N.....	15 10 08	.....	.....	.....	.....	
7	.....	.....	.....	.....	.....	.....	.....	Slight movement from a distant quake between 13h. 30m. and 14h. 30m. Distance and direction unknown.
10	.....	P_E.....	22 10 48	.....	.....	.....	.....	Distance about 1,640 km.; direction unknown.
		P_N.....	22 10 54	.....	.....	.....	.....	
		S_E.....	22 13 40	.....	.....	.....	.....	
		S_N.....	22 13 44	.....	.....	.....	.....	
		L_E.....	22 15 20	.....	.....	.....	.....	
		L_N.....	22 14 56	.....	.....	.....	.....	
		M_E.....	22 13 54	.....	*2,500	.....	.....	
		M_N.....	22 13 54	.....	.....	*2,000	.....	
		F_E.....	22 40 00	.....	.....	.....	.....	
		F_N.....	22 45 00	.....	.....	.....	.....	
28	.....	P.....	15 45 52	.....	.....	.....	538	Direction probably W. or NW. (?).
		S.....	15 46 50	.....	.....	.....	.....	
		L_E.....	15 47 16	.....	.....	.....	.....	
		L_N.....	15 47 12	.....	.....	.....	.....	
		M_E.....	15 47 34	.....	*500	.....	.....	
		M_N.....	15 48 00	.....	.....	*700	.....	
		F_E.....	15 53 00	.....	.....	.....	.....	
		F_N.....	15 53 30	.....	.....	.....	.....	
28	.....	P.....	18 46 00	.....	.....	.....	1,529	Direction probably NW. (?).
		S.....	18 48 40	.....	.....	.....	.....	
		L.....	18 50 20	.....	.....	.....	.....	
		M.....	18 51 28	.....	*500	*500	.....	
		F.....	19 03 00	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1920			H. m. s.	Sec.	μ	μ	Km.	
Feb. 2	.....	eP_E	11 45 39	.....	.....	.....	.....	
		eP_N	11 45 32	.....	.....	.....	.....	
		eL_E	12 38 15	.....	.....	.....	.....	
		eL_N	13 19 50	.....	.....	.....	.....	
		M_E	13 19 58	22	40	.....	.....	
		M_N	13 22 53	21	.....	10	.....	
		F_E	13 50 ..	.....	.....	.....	.....	
		F_N	13 30 ..	.....	.....	.....	.....	
10	.....	iP_E	22 07 48	.....	.....	.....	.....	About 46 sec. after the beginning, the stylus of N went off the paper and caught. The stylus of E went off at 22:09:08, but freed itself at 22:14:20. The amplitudes are measured to the edge of the paper. Felt in Porto Rico.
		iP_N	22 07 48	.....	.....	.....	.....	
		iL_E	22 08 02	.....	.....	.....	.....	
		iL_N	22 08 02	.....	.....	.....	.....	
		M	.. .. ..	.....	8,400	8,500	.....	
		C_E	22 16 ..	17	.....	.....	.....	
		F_E	23 33 ..	12	.....	.....	.....	
10	.....	eP_E	22 37 34	.....	.....	.....	.....	Slight shock during the end portion of the large one.
		eS_E	22 37 56	2	10	.....	.....	
		F_E	22 42 ..	.....	.....	.....	.....	
11	.....	eP_E	0 10 53	.....	.....	.....	.....	N not recording.
		M_E	0 11 39	.....	20	.....	.....	
		F_E	0 17 ..	5	.....	.....	.....	
11	.....	eP_N	8 13 15	.....	.....	.....	.....	
		S_E	8 13 38	.....	.....	.....	.....	
		S_N	8 13 37	.....	.....	.....	.....	
		M_E	8 14 16	7	30	.....	.....	
		M_N	8 14 32	7	.....	40	.....	
		F_E	8 22 ..	5	.....	.....	.....	
		F_N	8 20 ..	5	.....	.....	.....	
12	.....	iP_E	0 26 59	.....	.....	.....	.....	
		iP_N	0 26 58	.....	.....	.....	.....	
		eL_E	0 27 11	.....	.....	.....	.....	
		eL_N	0 27 34	.....	.....	.....	.....	
		M	0 28 14	11	190	330	.....	
		C	0 30 ..	7	.....	.....	.....	
		F	0 39 ..	6	.....	.....	.....	
12	.....	eP_E	15 39 35	.....	.....	.....	.....	
		eP_N	15 39 37	.....	.....	.....	.....	
		M_E	15 40 30	.....	10	.....	.....	
		F	15 44 ..	.....	.....	.....	.....	
12	.....	eP_E	17 49 49	.....	.....	.....	.....	
		eP_N	17 49 52	.....	.....	.....	.....	
		S	17 50 08	.....	.....	.....	.....	
		M_E	17 50 45	8	90	.....	.....	
		M_N	17 50 29	.....	.....	110	.....	
		C	17 52 ..	.....	.....	.....	.....	
		F	18 00 ..	5	.....	.....	.....	
12	.....	eP_E	22 39 38	.....	.....	.....	.....	
		eP_E	22 39 48	.....	.....	.....	.....	
		M_E	22 40 10	.....	5	.....	.....	
		F_E	22 42 ..	.....	.....	.....	.....	
		F_N	22 43 ..	.....	.....	.....	.....	
21	.....	eP_E	13 54 11	.....	.....	.....	.....	
		P_N	13 54 11	.....	.....	.....	.....	
		S_E	13 54 21	2	.....	.....	.....	
		S_N	13 54 27	.....	.....	.....	.....	
		M_E	13 54 50	.....	80	.....	.....	
		M_N	13 54 47	.....	.....	100	.....	
		C	13 56 ..	4	.....	.....	.....	
		F	14 02 ..	4	.....	.....	.....	

VERMONT. *U. S. Weather Bureau, Northfield.*

1920			H. m. s.	Sec.	μ	μ	Km.
Feb. 2	.....	e	11 47	.....	.....	.....	.....
		eL	12 29 ..	20	.....	.....	.....
		L	12 44 30	18	.....	.....	.....
		L	13 24 ..	18	.....	.....	.....
		F	13 50 *ca.*	.....	.....	.....	.....
10	.....	e	22 12 48	.....	.....	.....	.....
		S	22 17 11	.....	.....	.....	.....
		L	22 19 22	.....	.....	.....	.....
		L	22 22 ..	14	.....	.....	.....
		F	23 35 *ca.*	.....	.....	.....	.....
22	.....	e	17 51 40	.....	.....	.....	.....
		S	18 00 56	.....	.....	.....	.....
		F	18 05 ..	.....	.....	.....	.....

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

CANADA. *Dominion Observatory, Ottawa.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 2	.....	PR_1?	11 42 44	.....	.....	.....	12,500 *ca.*	Early phases lost.
		e?	11 48 16	.....	.....	.....	.....	Distance from eL and LR_1, both well marked.
		eL	12 13 ..	50	.....	.....	.....	
		L	12 28 ..	23	.....	.....	.....	
		L	12 40 ..	18	.....	.....	.....	
		L	12 54 ..	17	.....	.....	.....	
		L	13 11 ..	16	.....	.....	.....	
		LR_1	13 15 ..	25	.....	.....	.....	
		L	13 25 ..	22	.....	.....	.....	
		L	13 35 ..	18	.....	.....	.....	
		L	13 45 ..	16	.....	.....	.....	
		L_E	14 09 ..	13	.....	.....	.....	
		F	.....	.....	.....	.....	.....	Lost in changing the sheets.
			HALIFAX RECORD.					
		PR$_1$?	*11 44 58*	.....	.....	.....	.....	Epicenter probably in the East Indies.
		e?	*11 50* ..	.....	.....	.....	.....	
		eL	*12 15 30*	.....	.....	.....	.....	
7	.....	i_N	12 01 28	.....	.....	.....	.....	Early phases lost in heavy micros.
		eL	12 05 to 12 09 ..	15	.....	.....	.....	
8	.....	L	6 54 to 7 10 ..	19	.....	.....	.....	Faint traces only.
10	.....	e?$_E$	9 42 20	.....	.....	.....	.....	
		L?$_E$	9 46 16	.....	.....	.....	.....	
		L?	10 11 ..	.....	.....	.....	.....	
		L_E	10 19 to 10 40 ..	18	.....	.....	.....	
		L_E	11 10 to 11 15 ..	18	.....	.....	.....	
		L	11 20 ..	.....	.....	.....	.....	
		F	11 40..	.....	.....	.....	.....	
10	.....	*O*	22 07 22	.....	.....	.....	2,900	
		P	22 13 09	.....	.....	.....	.....	
		S_N	22 17 44	.....	.....	.....	.....	
		L_E	22 20 20	.....	.....	.....	.....	
		L	22 22 to 22 31 ..	21	.....	.....	.....	
		L	22 35 to 22 47 ..	15	.....	.....	.....	
		L	22 50 ..	14	.....	.....	.....	
		L	23 06 ..	13	.....	.....	.....	
		L_E	23 25 ..	13	.....	.....	.....	
11	.....	F	0 50 ..	.....	.....	.....	.....	
		O	22 07 26	.....	.....	.....	2,610	
		P	22 12 44	.....	.....	.....	.....	
		S	22 17 08	.....	.....	.....	.....	
12	.....	e_E	0 35 02	.....	.....	.....	.....	
		eL	0 41 ..	.....	.....	.....	.....	
		F	0 55 ..	.....	.....	.....	.....	
22	.....	i	17 47 25	.....	.....	.....	.....	
		i	17 56 51	.....	.....	.....	.....	
		e_E	17 59 36	.....	.....	.....	.....	
		L?	18 10 to 18 25 ..	.....	.....	.....	.....	
		F	18 35 ..	.....	.....	.....	.....	
28	.....	*O*	18 44 *ca.*	.....	.....	.....	(5,000)	
		P?	18 52 30	.....	.....	.....	.....	P on deformation instrument only. Early phases poor on the siesmographs, due to micros.
		S?	18 59 12	.....	.....	.....	.....	
		eL	19 06 ..	.....	.....	.....	.....	
		L	19 15 ..	25	.....	.....	.....	
		F	19 25 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

CANADA. *Dominion Meteorological Service, Toronto.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 1								Gas out when other station records quake.
2		e?	11 33 18					
		e?	11 34 36					
		P	11 40 48					
		e	11 42 12					
		e	11 43 36					
		eS	11 52 30					
		iL	12 10 12					
		L	12 27 42					P not defined.
		M	12 38 06		*7,300		11,080?	
2		P & S.						Merged into previous quake; disastrous quake reported from Province of Minas Geraes, Brazil.
		iL	13 31 54					
		L	13 38 06					
		M	13 41 12		*2,800			
		eL	14 00 30					
		F						Lost, inspecting the instrument.
3		eL	7 49 54					Gradual thickening, may not be seismic.
		M	7 53 00		*200			
		F	7 57 36					
7		eL	12 06 36					
		iL	12 08 00					
		M	12 09 00		*400			
		F	12 24 36					
7		L	16 25 06					
		eL	16 30 18					
		M	16 34 54		*300			Thickening.
		L	16 41 00					
7		L	16 52 42					
		M	16 55 18		*100			
		L	17 06 18					Do.
		F	17 10 42					
8		eL	6 59 42					
		M	7 01 48		*200			
		F	7 07 54					
10		L	9 48 30					
		L	10 11 54					
		eL	10 16 12					
		M	10 21 48		*800			
10		eL	11 06 48					
		M	11 13 24		*300			
		F	11 34 00					
10		L	13 03 42					
		F	13 08 36		*100			May not be seismic.
10		eP	22 13 18					P well defined.
		iS	22 18 00				2,990	
		iL	22 20 24					
		M	22 25 12		*3,000			
11		F	1 26 18					
12		L	0 31 06					
		L	0 33 06					
		eL	0 42 06					
		M	0 44 12		*200			
		F	1 15 12					
15		L	15 47 06					
		F	15 50 30		*50			May not be seismic.
20		L	12?37 12		*50			Small micros going on.
22		L	17 54 00					
		L	17 57 06					
		M						Changing paper.
28		eL	16 04 24					
		M	16 07 06		*200			Gradual thickening.
		F	16 12 12					
28		eL	19 06 06					P and S not recorded.
		eL	19 10 54					
		eL	19 16 18		*50			
		F	19 53 18					

* Trace amplitude.

TABLE 2.—*Instrumental Reports, February, 1920*—Continued.

CANADA. *Dominion Meteorological Service, Victoria.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 1		P or L.	15?28 43					
		M	15 33 08		*200			
		F	15?38 03					
2		P	11 35 11				9,790	
		S	11 46 00					
		L	12 05 41					
		M	12 10 36		*7,500			
				VERTICAL.				
		P	*11 35 25*	*3*			9,700	
		S	*11 46 00*	*12*				
		L	*12 04 45*	*16*				
		M	*12 13 40*	*17*	*70*			
2		P & S.						Merged into former quake; quake occurred at Minas Geraes, Brazil. Severest on record for that region.
		L	13 45 31					
		M	13 48 57		*4,000			
		F	16 07 39					
				VERTICAL.				
		M	*13 42 00*	*23*	*60*			
2		P	16?57 20					
		M	17 32 45		*400			
		F	18 01 46					
3		P	7?18 31					
		M	7 24 55		*200			
		F	7 33 46					
3		P	15?37 13					
		M	15 42 08		*100			
		F	15 48 02					
3		P or L.	20?23 28					
		M	20 29 52		*100			
		F	20?36 45					
7		P	12?13 24					
		L	12 15 51					
		M	12 20 46		*400			
		F	12 33 56					
7		P	15?40 27					
		L	15 48 49					
		M	16 08 59		*400			
		F	16 58 09					
8		P	6?32 38					
		L	6 40 01					
		M	6 42 58		*400			
8		P	7 01 41					
		L	7 07 35					
		M	7 11 01		*200			
		F	7 35 07					
10		P	9 36 04				4,180	
		S	9 42 01					
		L	9 50 27					
		M	9 58 02		*1,000			
10		M	10 47 34		*400			
		F	11 08 14					
10		P	22 15 48				5,850	
		S	22 23 16					
		L	22 23 39					
		M	22 40 35		*2,000			
11		F	0 55 57					
				VERTICAL.				
		M	*22?40* ..	*12*	*6*			
15		L	16 06 43					
		M	16 09 40		*200			
		F	16 21 28					
20		S	12 27 18					May be quake reported in Spain.
		L	12 34 11					
		M	12 47 57		*100			
		F	12 58 46					
22		P	17 52 12					
		S	17 55 07					
		L	17 58 33					
		M	17 59 31		*200		1,720	
		F	18 09 22					
25		P	23 16 15					
		S	23 20 17					
		L	23 25 40					
		M	23 31 37		*200		2,460	
27		P	7 35 54					
		M	7 57 02		*300			
28		P	19 02 33					
		L	19 18 46					
		M	19 28 36		*400			

* Trade amplitude.

The following station recorded no earthquakes during February, 1920:

CALIFORNIA. *Theosophical University, Point Loma.*

Reports for February, 1920, have not been received from the following stations:

ALASKA. Sitka, U. S. C. & G. Survey.
DISTRICT OF COLUMBIA. Washington, D. C., Georgetown University.
KANSAS. Lawrence, University of Kansas.
MISSOURI. St. Louis, St. Louis University.
NEW YORK. Buffalo, Canisius College; New York, Fordham University.

For the reports of the stations at the University of California, Berkeley, Calif., and at the Lick Observatory, Mount Hamilton, Calif., see *Bulletin of the Seismographic Stations, University of California.* For the report of the University of Santa Clara station, see *Record of the Seismographic Stations, University of Santa Clara.*

SEISMOLOGICAL DISPATCHES.[1]

Buenos Aires, Februarry 2, 1920.—Dispatches from the state of Minas Geraes, Brazil, report that an earthquake Sunday shook down a number of houses in the country districts, creating great panic amongst the inhabitants. The dispatches say that in intensity the earth shock is without precedent in that region. (Associated Press.)

[1] Collected by the organization indicated, and reported by the Seismological Station, Georgetown University, Washington, D. C.

Mexico City, Mexico, February 6, 1920.—Earth shocks were felt at 12.50 o'clock this morning in the Vera Cruz region, according to report. (Associated Press.)

Paris (Haver), February 16, 1920.—The ministry colonies reported to-day that a tidal wave had swept over the French possessions in Oceania in the Pacific. The damage caused was important, the ministry added, and the losses were great on Makalea Island. (Associated Press.)

Cadiz, Spain, February 20, 1920.—A slight earthquake occurred yesterday at Benemargosa, Grazalema, and other centers of Andalusia. Considerable damage was done to various hamlets and villages but no loss of life was reported. (Associated Press.)

Rome (Havas), February 23, 1920.—Tiflis dispatches say that a great earthquake has occurred in the district of which the town of Gori is the center. There have been numerous casualties and serious damage. (Associated Press.)

Washington, D. C., February 28, 1920.—Two earthquakes occurred in the South Pacific Ocean to-day, resulting in the breaking of both South American cables. No further details are available. (Associated Press.)

Washington, D. C., February 28, 1920.—A report on the breaking of the cables, both of which were south of Callao, has been made to the Navy Department by the cable companies, but the department has received no reports concerning the disturbances from ships or wireless stations in the Pacific. (Associated Press.)

Chart I. Hydrographs of Several Principal Rivers, February, 1920.

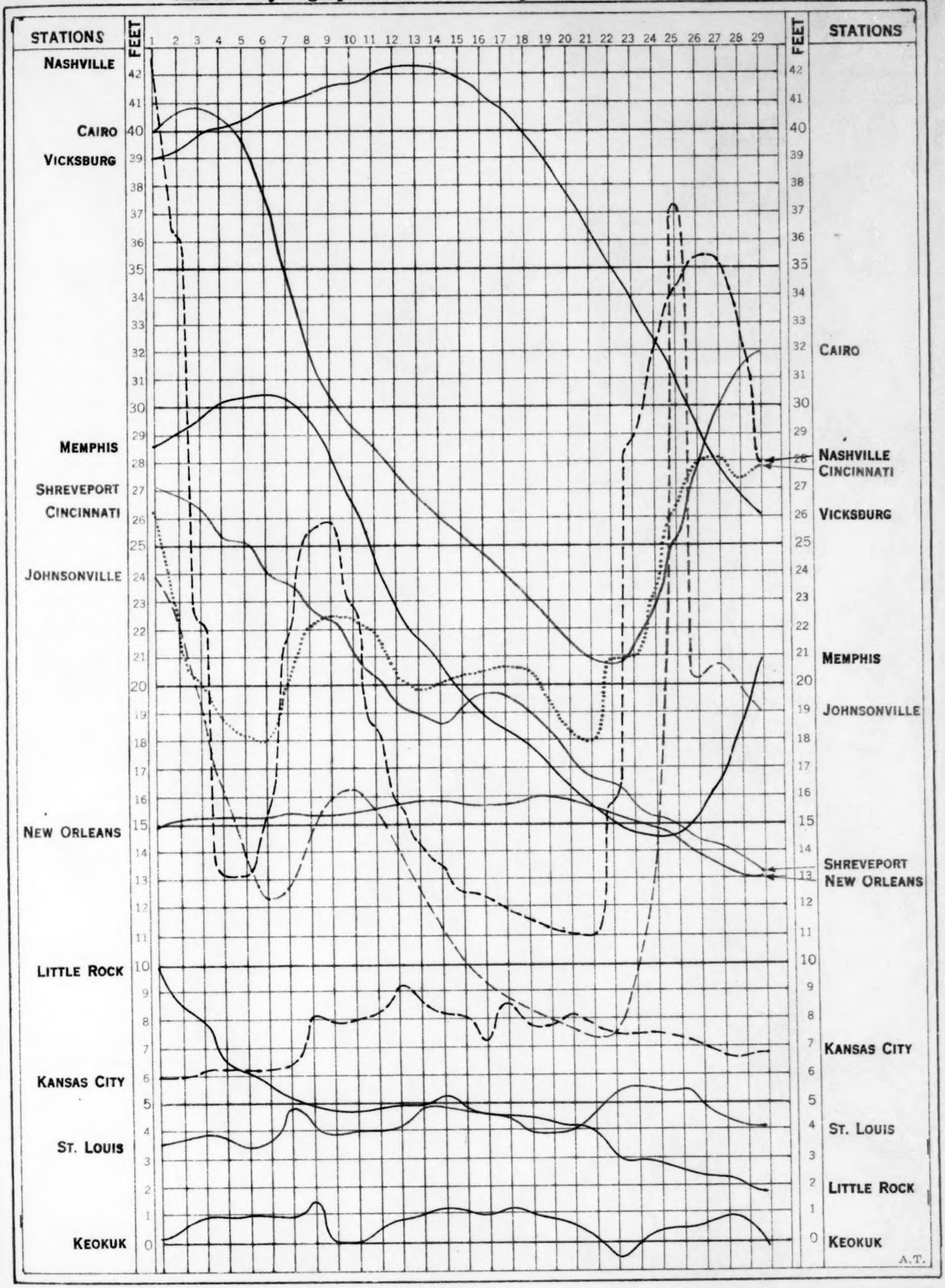


Chart II. Tracks of Centers of High Areas, February, 1920.

(Plotted by R. H. Weightman, Meteorologist.)

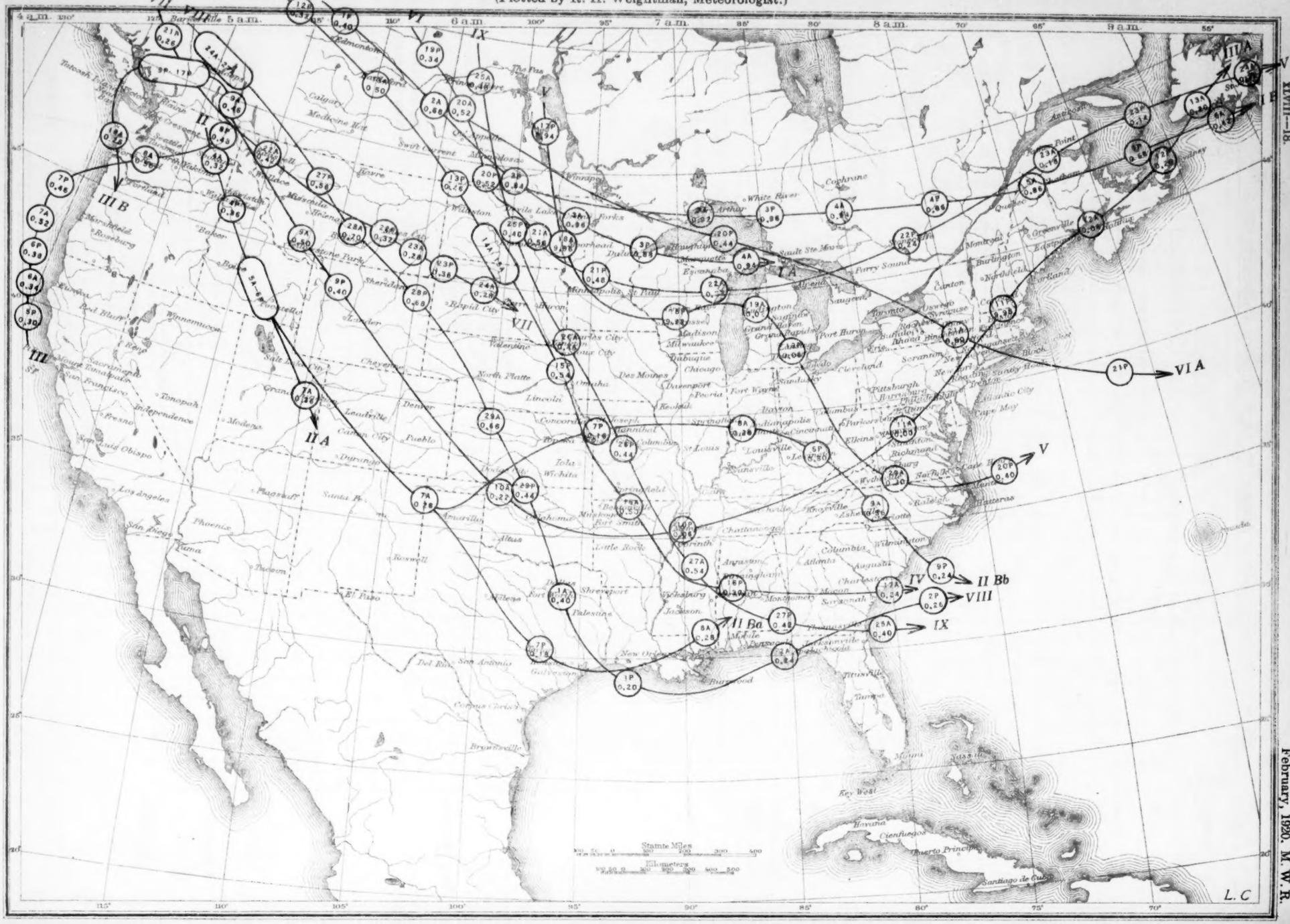


Chart III. Tracks of Centers of Low Areas, February, 1920.

Chart III. Tracks of Centers of Low Areas, February, 1920.

(Plotted by R. H. Weightman, Meteorologist.)

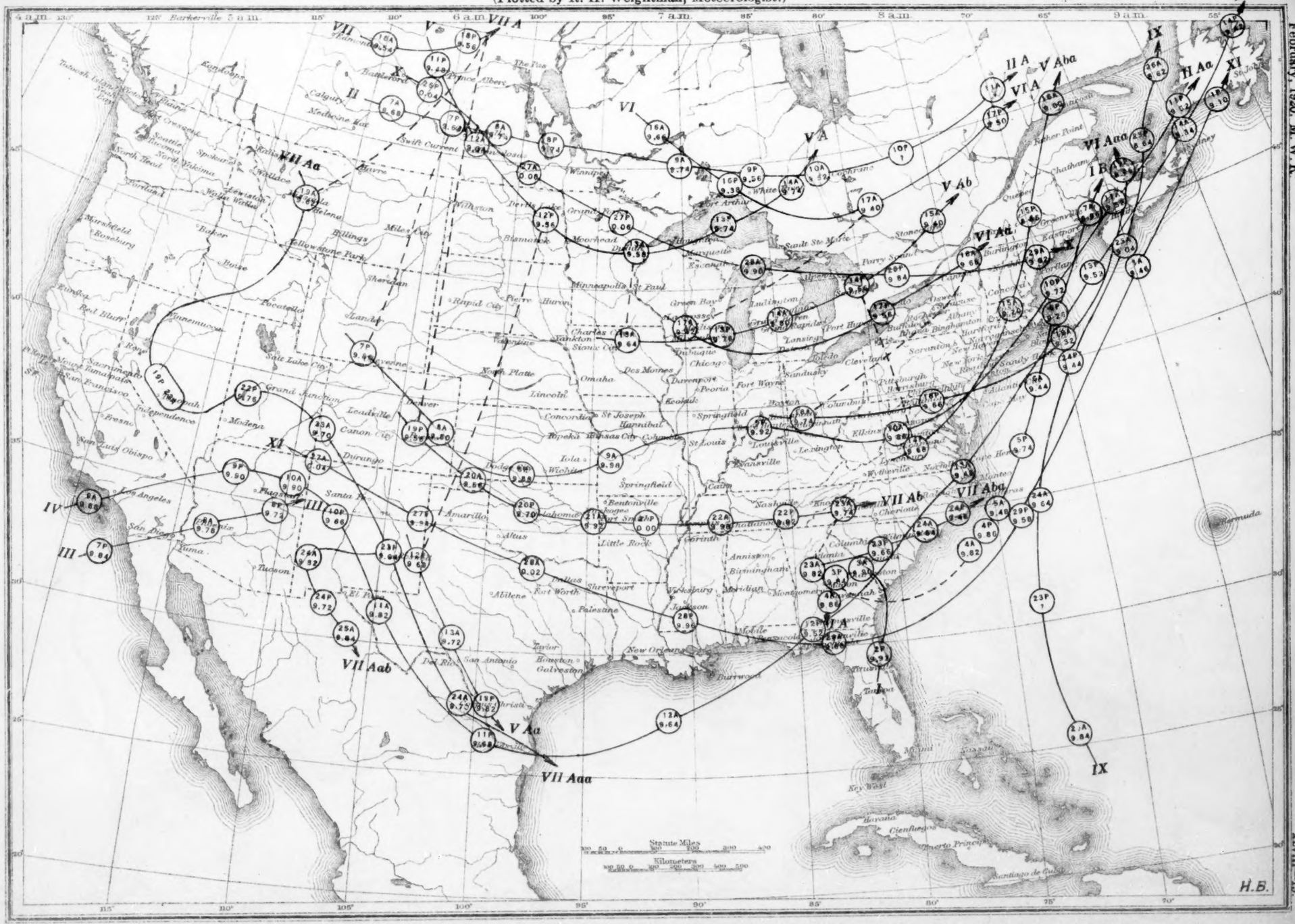


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, February, 1920.

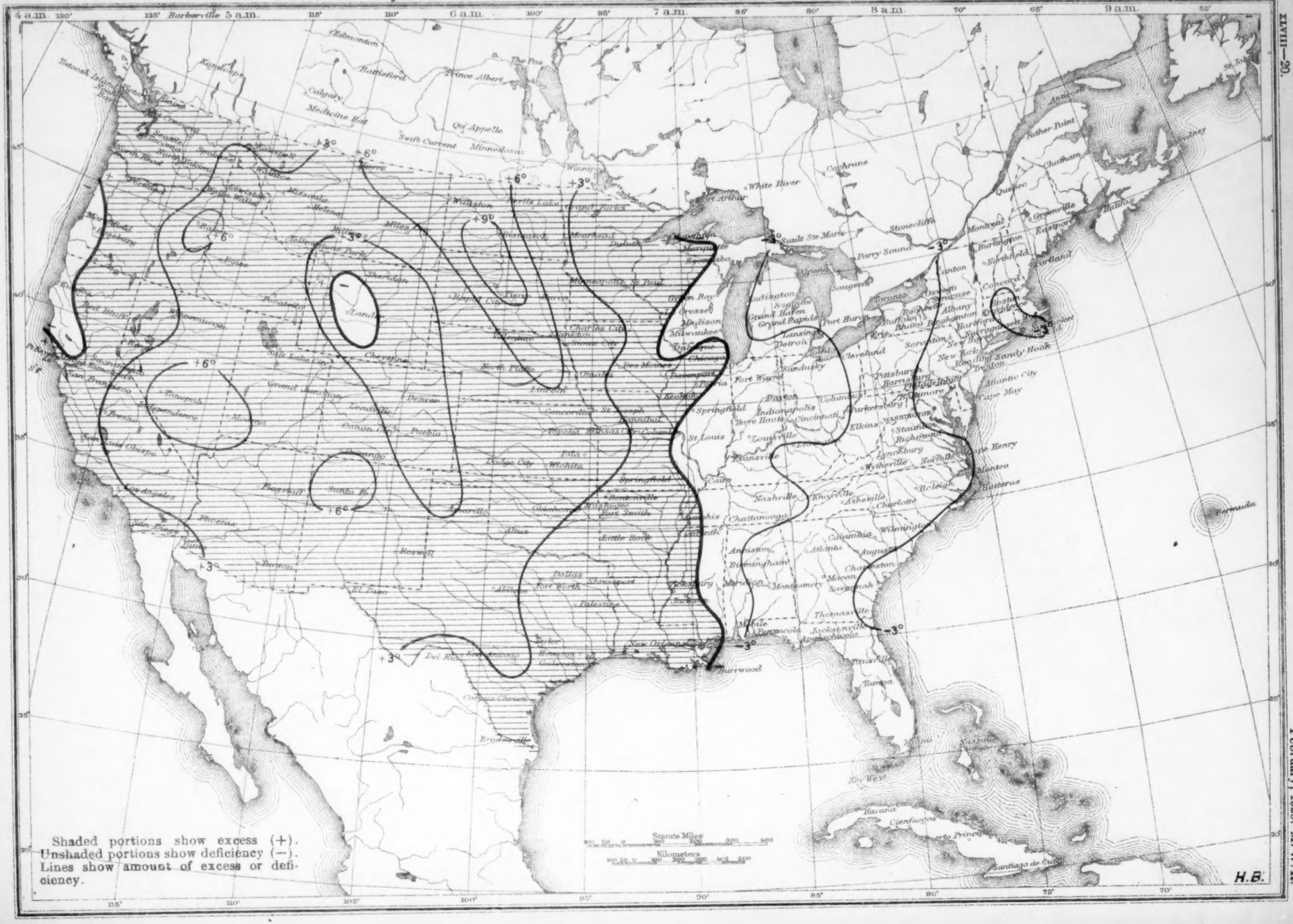


Chart V. Total Precipitation, Inches, February, 1920.

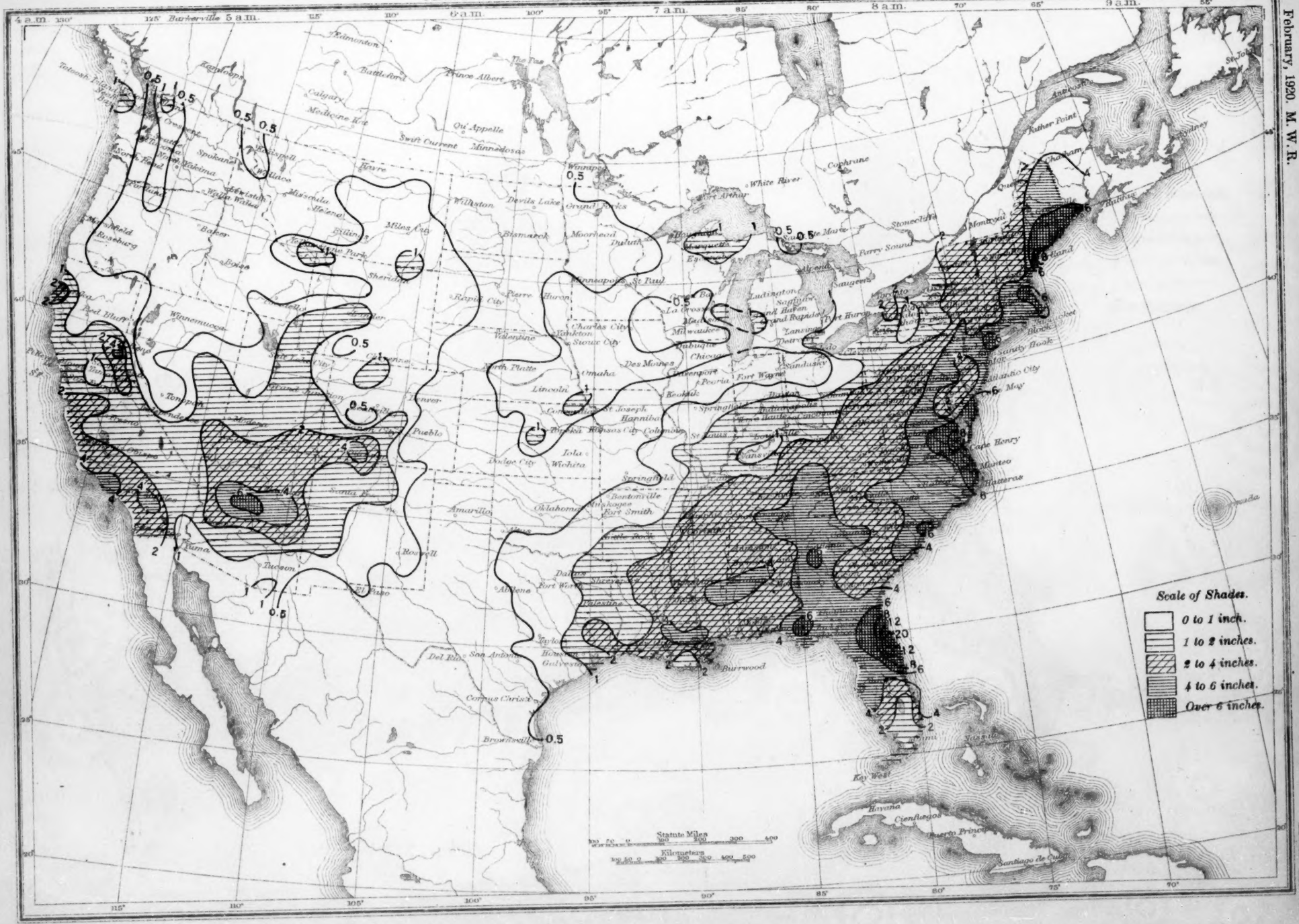


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, February, 1920.

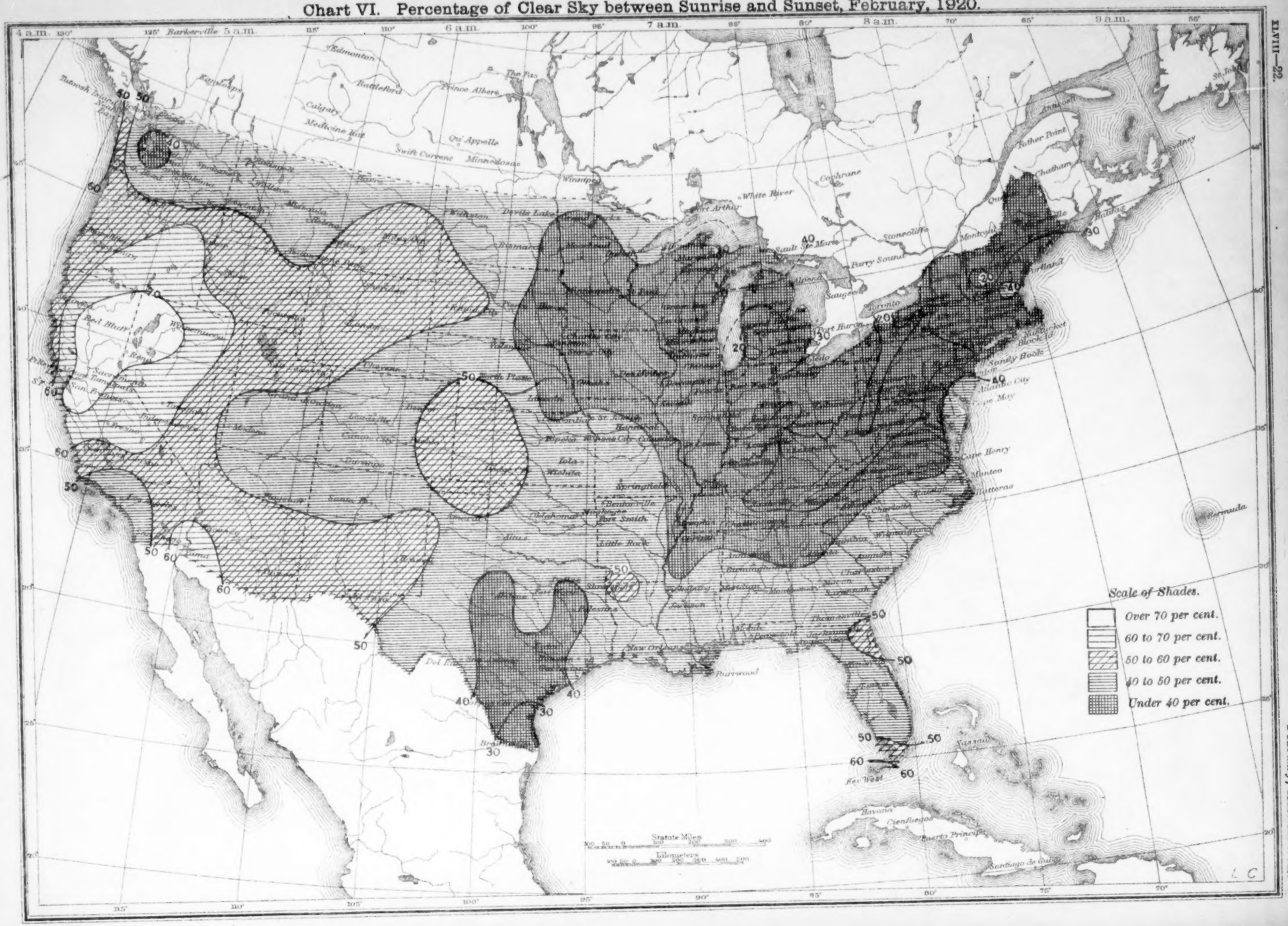


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, February, 1920.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, February, 1920.

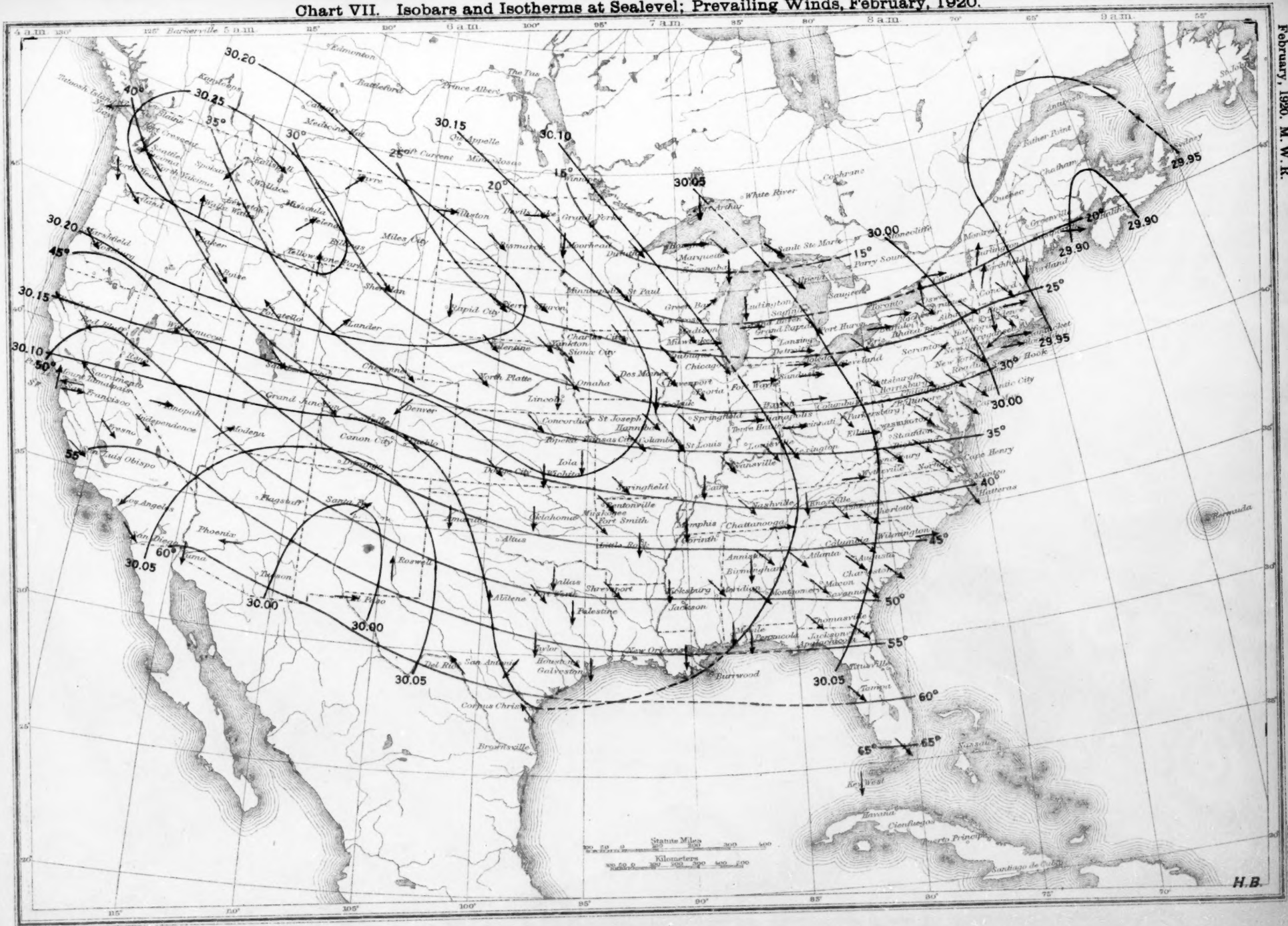


Chart VIII. Total Snowfall, Inches, February, 1920.

Chart IX. Weather Map of North Atlantic Ocean, February 5, 1920.

(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, February 5, 1920.

(Plotted by F. A. Young.)

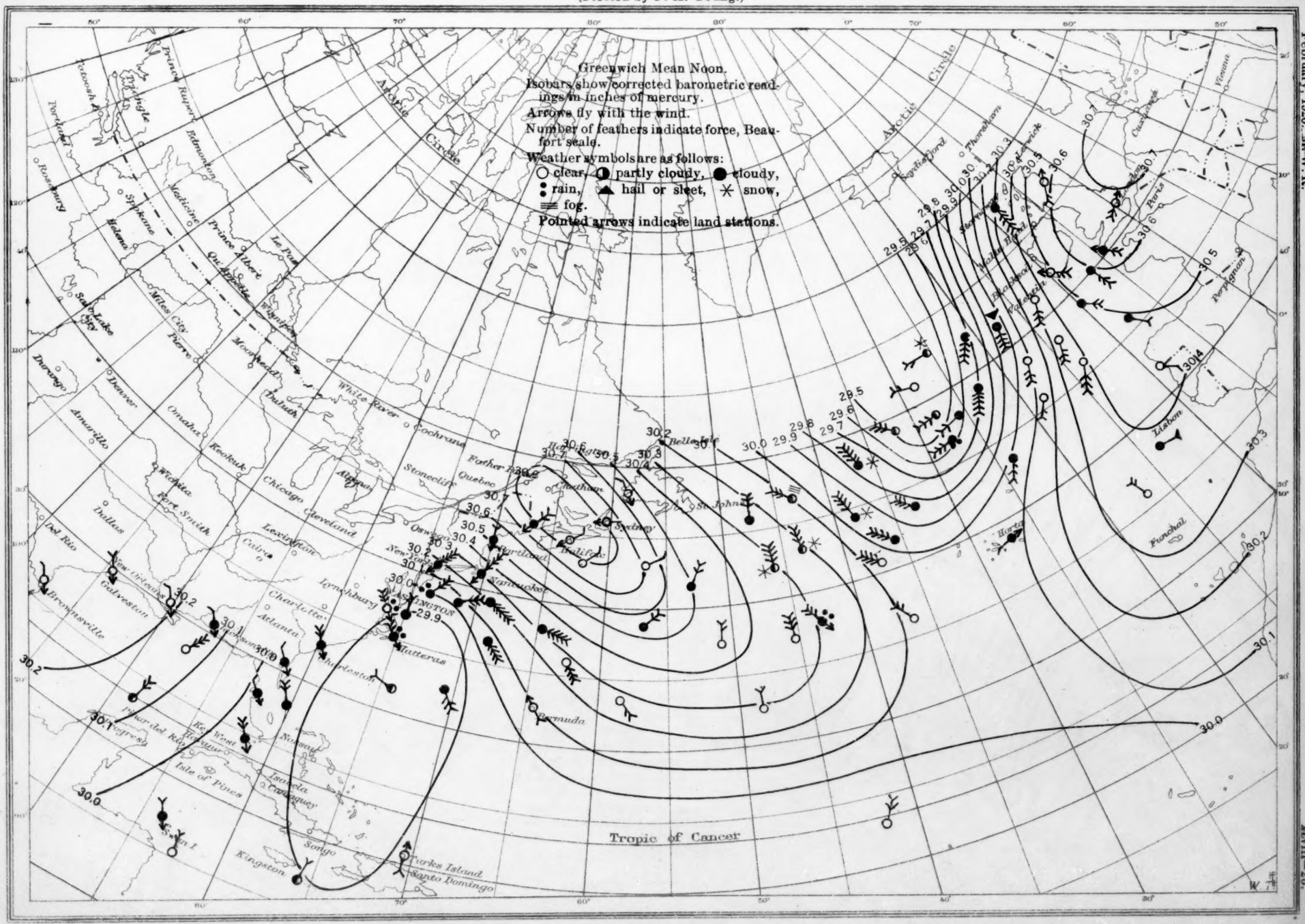


Chart X. Weather Map of North Atlantic Ocean, February 6, 1920.

(Plotted by F. A. Young.)

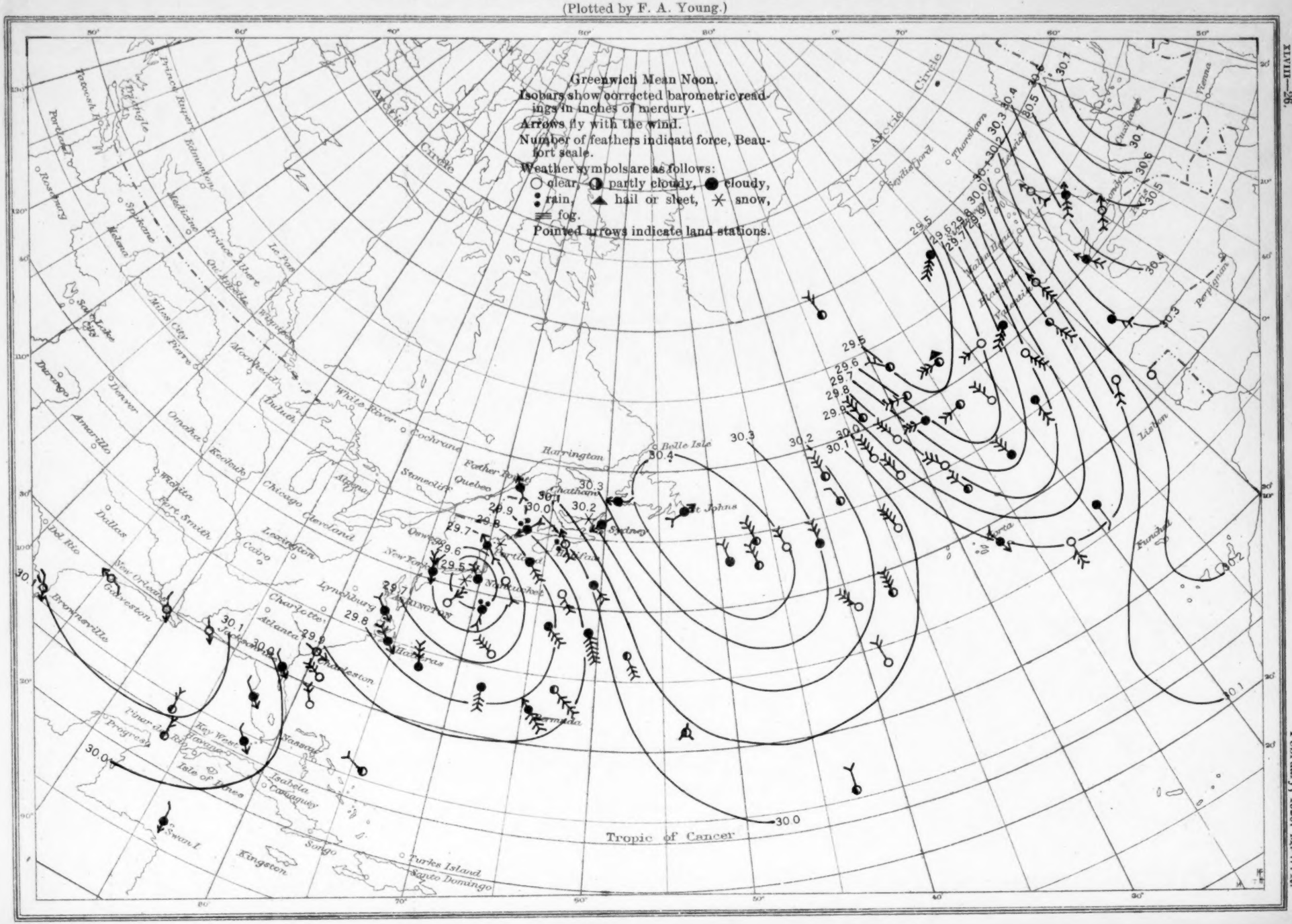


Chart XI. Weather Map of North Atlantic Ocean, February 7, 1920.

(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, February 7, 1920.

(Plotted by F. A. Young.)

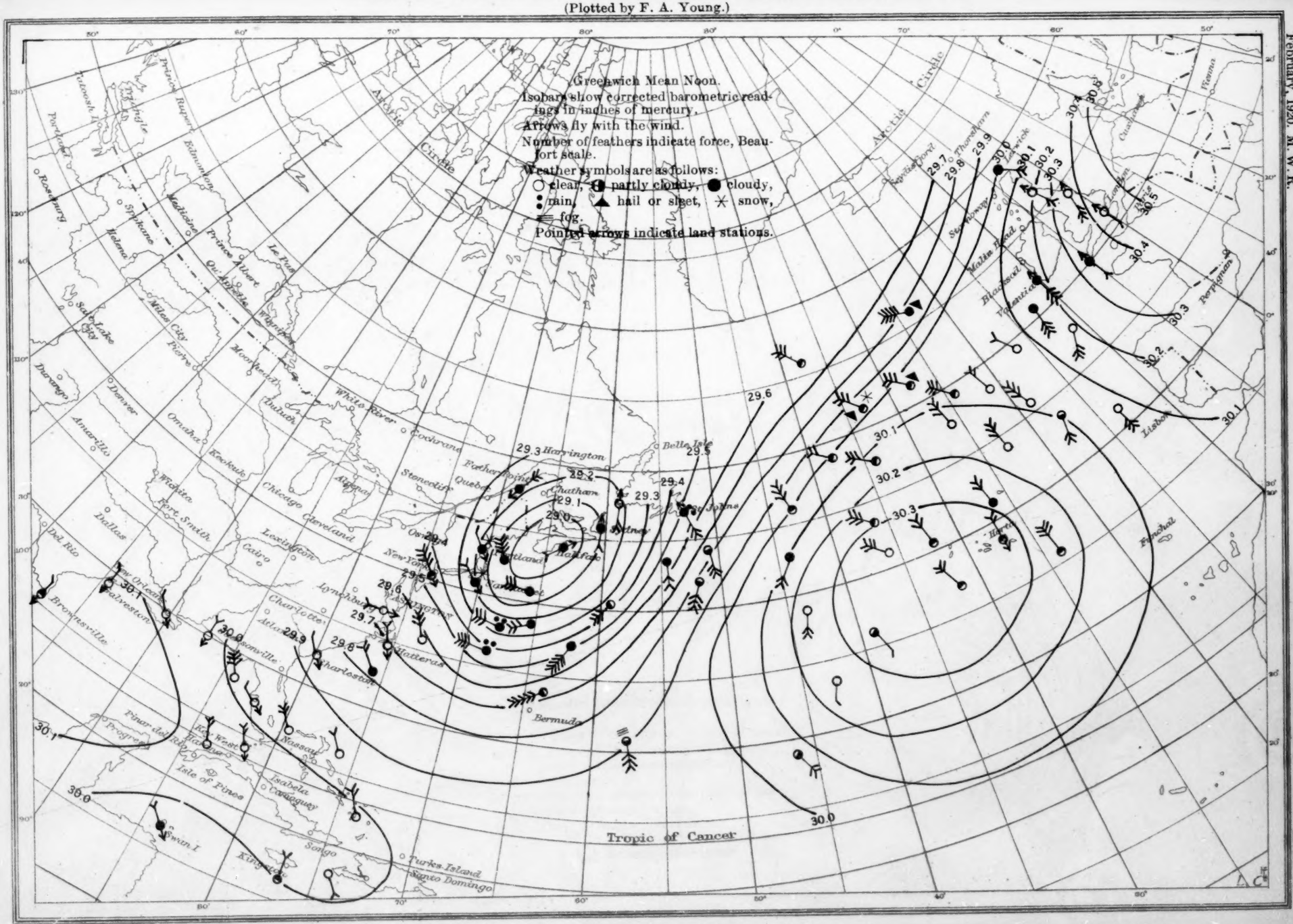


Chart XII. Weather Map of North Atlantic Ocean, February 15, 1920.

(Plotted by F. A. Young.)

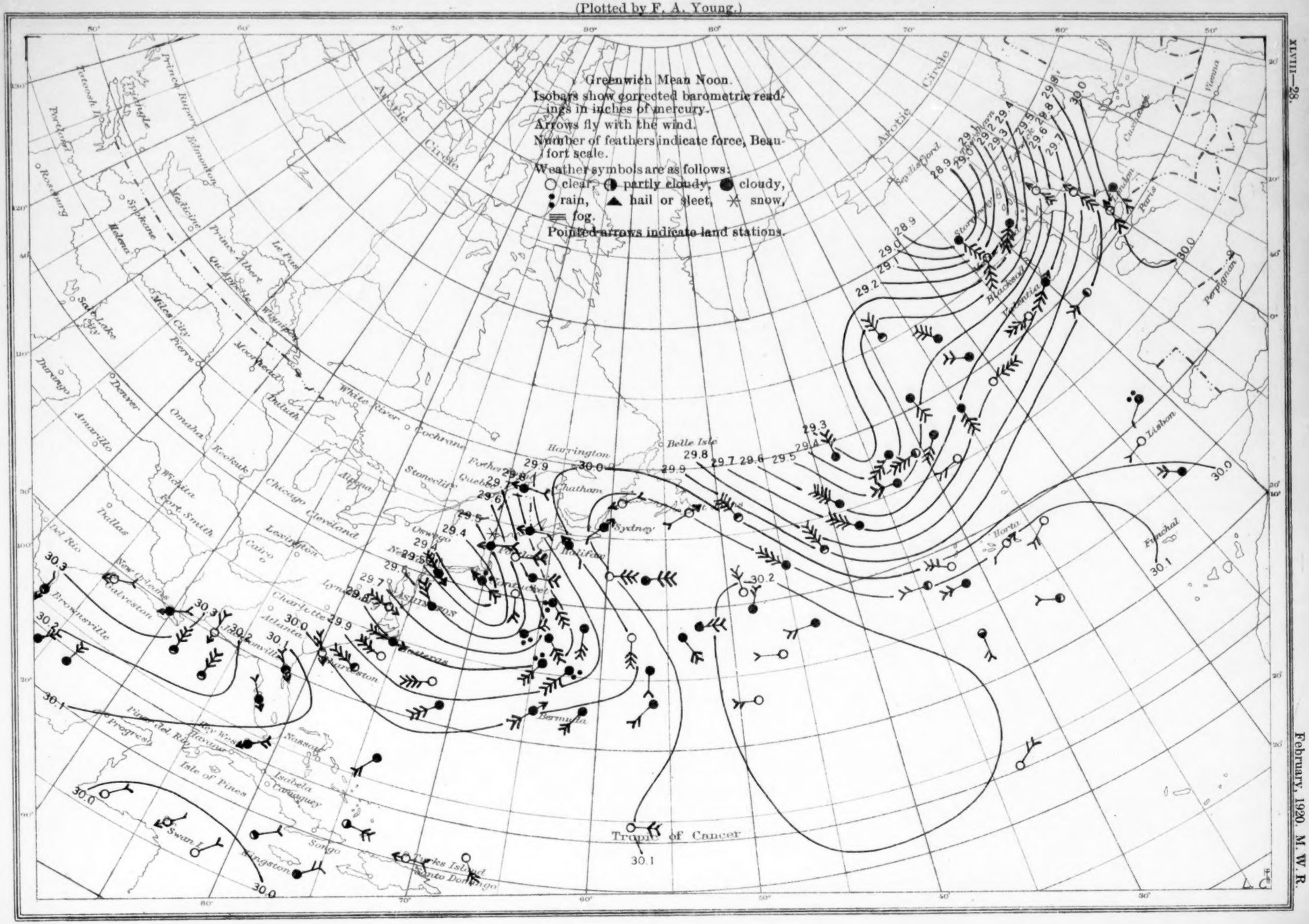


Chart XIII. Weather Map of North Atlantic Ocean, February 26, 1920.

(Plotted by F. A. Young.)

Chart XIII. Weather Map of North Atlantic Ocean, February 26, 1920.

(Plotted by F. A. Young.)

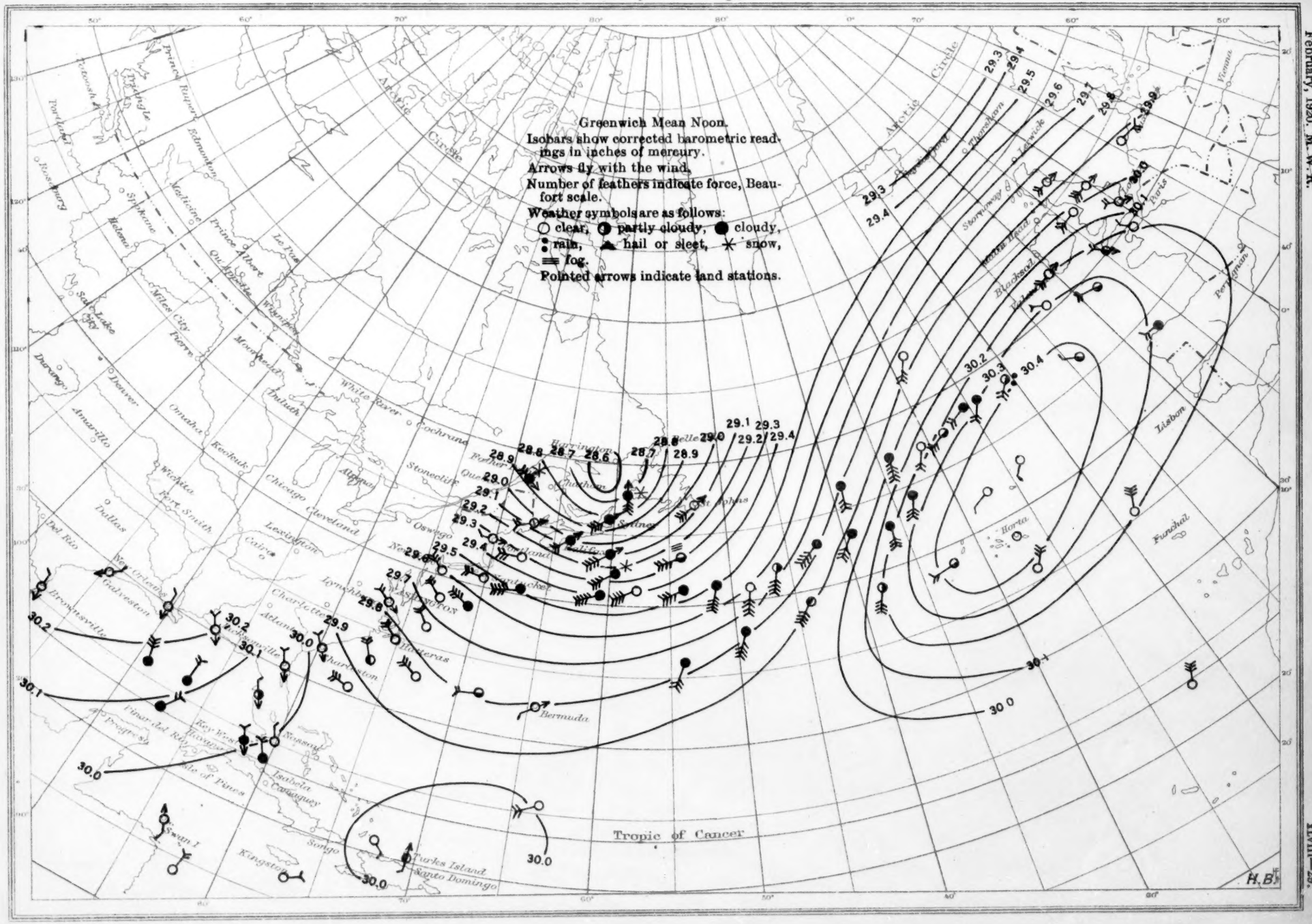
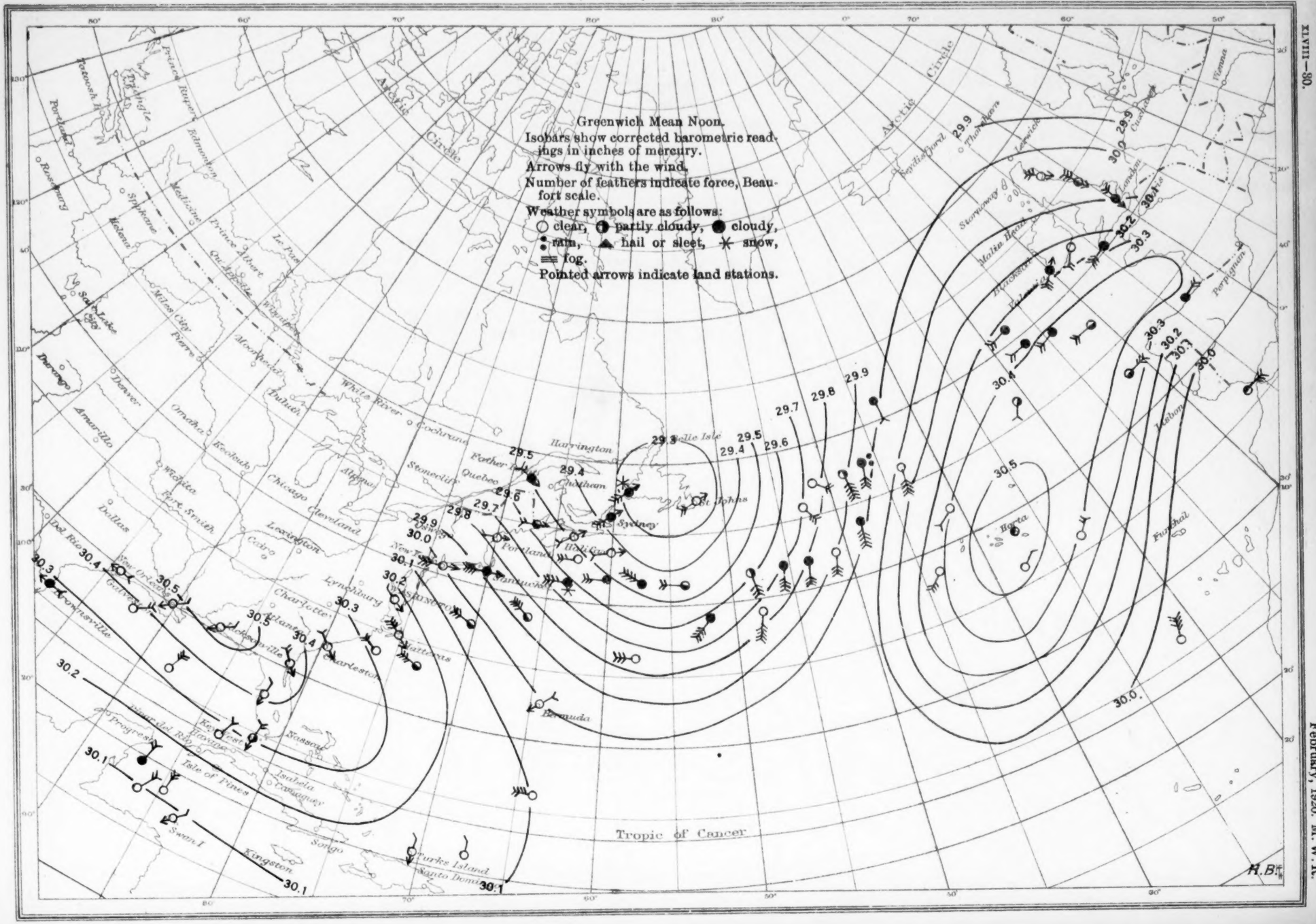


Chart XIV. Weather Map of North Atlantic Ocean, February 27, 1920.

(Plotted by F. A. Young.)


Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Tropic of Cancer
Arctic Circle
Antarctic Circle
H.B.

XLVIII—30.

February, 1920. M. W. R.